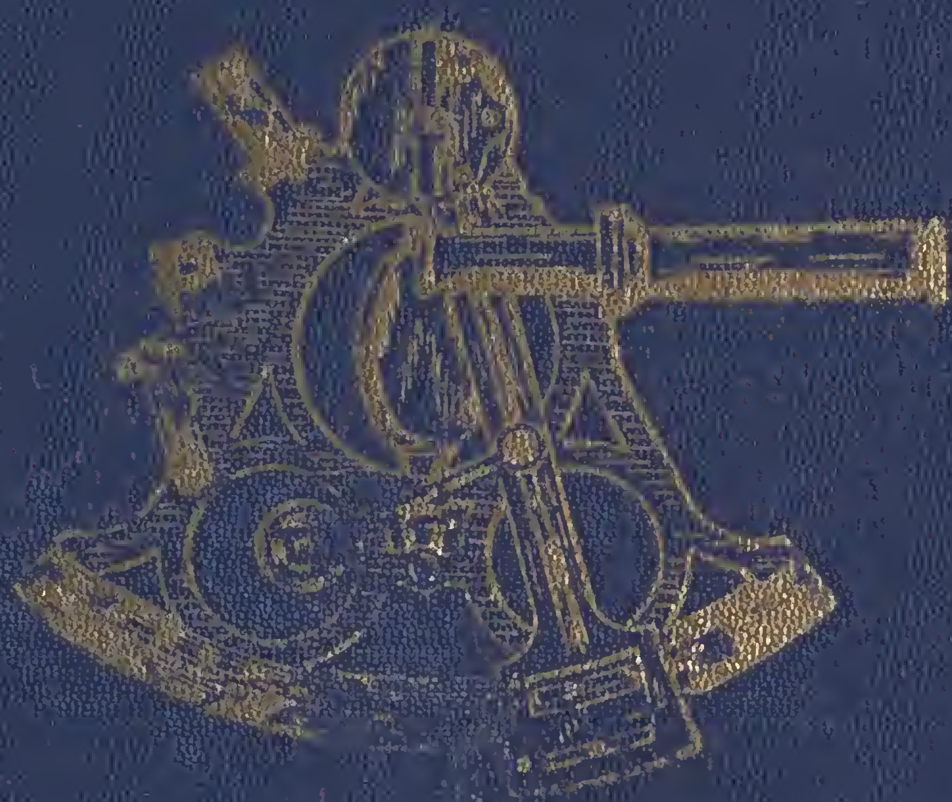
THE SELF-INSTRUCTOR IN NAVAGATION



and

PRACTICAL GUIDE

Third Edition

CAPT. W. J. SMITH

THE

SELF-INSTRUCTOR IN NAVIGATION

.... AND ....

PRACTICAL GUIDE

.... TO THE ....

Examinations of the U. S. Government Inspectors

... FOR ....

MASTERS AND MATES OF OCEAN GOING STEAMSHIPS AND SAILING VESSELS, AND FOR ALL INLAND GRADES

WITH ILLUSTRATIONS

THIRD EDITION REVISED AND ENLARGED

.... BY ....

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Ocean Steamship Master

Graduate of Trinity Nautical College, Member of The National Geographic Society

Author of "The Compass, Log, Lead and Lookout"
Author of "Practical Compass Adjustment"

Holding Master's Unlimited Ocean and Inland License, American and British—Instructor in Navigation and Nautical Astronomy—Successful Adjuster of Iron and Steel Ships' Compasses—Inventor of the Fogometer—Principal of The Seattle Navigation School.

SEATTLE WASHINGTON, U. S. A.

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To The American Associations of Master, Mates and Pilots of the United States and Territories, this Self-Instructor and Practical Guide is respectfully and faithfully dedicated.

PREFACE TO FIRST AND SECOND EDITIONS.

In placing this guide before his brother seamen, the author makes no attempt at any great display of originality. True, many of the questions contained herein are taken from his own chart room work book, and are from observations made personally at sea (principally while in the Oriental passenger trade from Puget Sound ports), and worked over again with greater accuracy, using up-to-date nautical almanac elements; but these problems are, for the most part, similar to those found in other works. The present object is rather to put into the hands of aspiring mariners, a handy self-guide, to enable him with the aid of his epitome, or book of nautical tables, to prepare himself successfully to pass his examinations before the Local Inspectors without fear of failure, and with credit to himself as an up-to-date navigator.

A sufficient number of examples are clearly worked out, or given as exercises, to ensure proficiency. Some are worked to seconds of arc, some to half minutes and others to the nearest minute only; and in a few cases, the shortest sea method, consistent with reasonable accuracy, is also shown. Nories' Tables have been used almost throughout, and the numbers of the tables in other epitomes, corresponding to these, are given, so that the student may readily find and use the table he may desire. The answers to Examples for Practice will be found at the end of the guide, as also the Nautical Almanac Elements, etc., required in their computation. And several very useful and important items, not usually found in works of this kind, but very helpful to the navigator, have been added.

The practical mind of a seaman naturally recoils from tedious, unnecessary exactness, and for this reason the writer has taken great pains to render the entire work as commonplace as the limits of necessity and the strictness of the United States Inspectors will allow. The volume is based on a life study and

observation in all climes, and under all circumstances; at the same time, ideas gleaned from nautical men of repute have not been left out; and the simplest possible language has been used in explaining the various problems, and stating the rules for working them.

Unavoidable errors, such as are usual in a work of this kind, will doubtless catch the eye, but the intelligent student will understand why it is next to impossible to create such a work absolutely perfect. Errors, however, are exceedingly few in number. Should the nautical critic, or the "sea lawyer" look for literary gems in this work, it is needless to say that he will be grievously disappointed. The boy that goes to sea at fourteen, and remains under Neptune's sway for thirty years, has more to do than work himself into a star in the literary sky. Books of a like kind are imported into this country and sold at a high figure; and, because of this, the writer endeavors, by this American publication, to offer to seamen the same value at least, at a very much reduced cost.

In conclusion, if the young officer takes half as much pleasure in mastering these problems as the writer has experienced in working them out, he will be well paid for his studies. The Self-Instructor will stand or fall on its own merits.

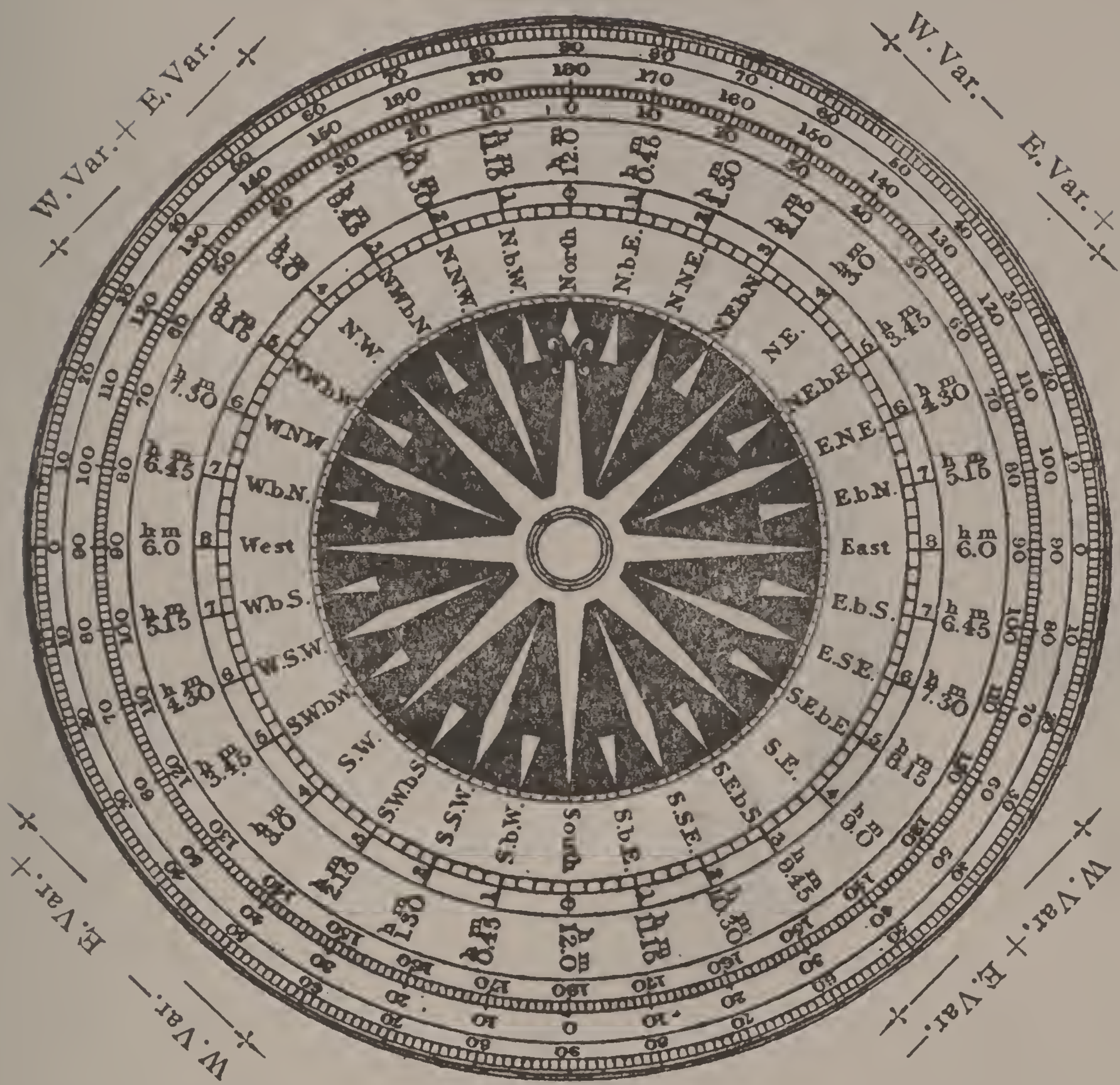
Seattle, Wash., U. S. A. W. J. S.

THIRD EDITION.

Owing to increased demand for "Self-Instructor" this Third Edition is published, and the Author expresses his heartiest gratitude to the Navigator, by whose appreciation of the Book as a real "help in times of need" another edition has been made possible. Thanks indeed to the Nautical Fraternity, Self-Instructor now wears an additional stripe on its uniform.

Seattle, Wash., U. S. A. July, 1912. W. J. S.

MARINER'S COMPASS



Easterly var. and easterly dev. are allowed to the right, and westerly to the left in any quadrant of the compass.

Easterly variation is allowed to the right and westerly to the left when reducing a mag. course to a true course. And dev. is allowed the same way when reducing a compass course to a mag. course.

Pts.	Angles	Pts.	Angles
¼	2° 48′ 45″	4¼	47° 48′ 45″
½	5° 37′ 30″	4½	50° 37′ 30″
¾	8° 26′ 15″	4¾	53° 26′ 15″
1	11° 15′ 00″	5	56° 15′ 00″
1¼	14° 03′ 45″	5¼	59° 03′ 45″
1½	16° 52′ 30″	5½	61° 52′ 30″
1¾	19° 41′ 15″	5¾	64° 41′ 15″
2	22° 30′ 00″	6	67° 30′ 00″
2¼	25° 18′ 45″	6¼	70° 18′ 45″
2½	28° 07′ 30″	6½	73° 07′ 30″
2¾	30° 56′ 15″	6¾	75° 56′ 15″
3	33° 45′ 00″	7	78° 45′ 00″
3¼	36° 33′ 45″	7¼	81° 33′ 45″
3½	39° 22′ 30″	7½	84° 22′ 30″
3¾	42° 11′ 15″	7¾	87° 11′ 15″
4	45° 00′ 00″	8	90° 00′ 00″

LOGARITHMS.

1. *Logarithms* are numbers used for shortening arithmetical calculations. The word *logarithms* is usually contracted to *logs.* By means of logs, multiplication is converted into addition, and division into substraction.

A logarithm or log, consists of two parts separated by a decimal point. The part to the left is called the *index,* which we have to tell. The part to the right is called the *decimal part,* but generally, *the log,* and is given in Table 42 Bowditch, or 24 Norie.

2. *To Find the Index.*—The index is one less than the number of figures in the whole number; thus—

The index of 56 is 1. The index of 560 is 2. The index of 5607 is 3. The index of 56070 is 4.

The index of 560.7 is 2. This is according to the rule, for though there are four figures in 560.7, there are only *three* in the whole number 560. The figures read, five hundred and sixty decimal seven.

The index of 56.07 is 1; and it reads fifty-six decimal nothing seven. Two figures in the whole number; index 1.

The index of 5.607 is 0. Only one figure in the whole number here, and by the rule, one less gives index 0.

3. *To Find the Index of a Number All Decimals.*—Subtract the point and the number of nothings to the right of the point from 10.

Thus the index of .0478 is 8; for the point 1 and 1 nothing make 2, and 2 from 10 leave 8.

The index of .000721 is 6; for the point 1 and 3 nothings make 4, and 4 from 10 leave 6.

The index of .726 is 9; for the point 1 substracted from 10 leaves 9. The 10 that we substracted the decimal point and nothings from is supposed to be borrowed.

4. *To Find the Logarithm of a Number.*—

If the number consist of one or two figures the log will be found at the beginning of the table. Thus, the log of 48 is 1.681241.

If the number consist of three figures. Seek the three figures in the side column of the table, and the adjoining log under 0 will be the log required; thus, the log of 679 is 831870

If the number consist of four figures. Seek the first three figures in the left side column, and the fourth at the top of the table; and abreast of the three figures under the fourth is the log required. Thus, the log of 4728 is 674677.

If the number consist of five or more figures. Take out the log of the first four as explained above. Then from the difference column on the right of the table take the difference abreast of the log and multiply it by the remaining figures; score off from the right of the product as many figures as did remain, and add the others to the log taken out for the first four figures. For instance: Find the log of 27975. The log of 279 under 7 is 446692. The difference abreast of this is 155, which multiplied by 5 (the figure we could not find in the table) gives 775; score off one figure from the right of this, as we had but one figure to correct for, and we have 77 to be added to the log 446692, which gives us 446769, the log of 27975. Again: Find the log of 170908. The log of 1709, the first four figures is 232742. The difference is 255, which multiplied by 08, the remaining figures, gives 2040. Score off the two right-hand figures, because there were two figures we could not take out, and there is left 20 to be added to the log of the first four figures, giving us 232762, the log of 170908. The number with its index and corresponding log should appear thus, 170908.5.232762.

5. *To Find the Number Corresponding to a Logarithm*—

If the number be required to four figures only. Seek in the table for the log nearest the given one, and abreast of this in the left side column are the first three figures, and the fourth at the top of the column in which we found the nearest log.

If the number be required to five or more figures. Find the log next less to the given one, this will give the first four figures; subtract this log (taken from the tables) from the given log, annex as many ciphers, one at a time, to this remainder as there are figures wanted above four, and divide by

the difference found in the right side column abreast of the log. Thus: Find the number corresponding to 4.478307.

The next less log gives	3008	478278
Dividing by the diff.	145)	290 (2
		290

Annexing the 2 to 3008 we have 30082, the number wanted. The answer must always contain one more whole number than the index. The above index being 4, there must be five figures in the whole number.

MULTIPLICATION BY LOGARITHMS.

6. Take the logs of the numbers from the Table of Logarithms and *add* them together; the number corresponding to the sum will be the product required.

1. Multiply 27 by 5 by common logarithms.

Mult.	27	log.	1.431364
By	5	log.	0.698970 +
Answer	135.0		2.130334

Here the answer must contain three whole numbers, because the index is 2. Seek 130334 among the logs. It will be found opposite 135 under 0.

2. Multiply 21.31 by 423.2 by common logarithms.

Mult.	21.31	log.	1.328583
By	423. 2	log.	2.626546 +
Answer	9018		3.955129

The index of 21.31 is 1, because there are two whole numbers, and the index of 423.2 is 2, because there are three whole numbers. Now, take out the logs. For the log of 21.31, seek 213 in the left-hand side column, and abreast of this under 1 is the log 328583; place it with the index 1, as above. Seek 423 in the left side column, and abreast of this, under 2, is the log 626546; place this in like manner with its index 2. Add the two logs together, and seek the sum 955129 in the table. We

cannot find 955129 exact; then take 955110, which is the nearest. This is abreast of 901 under 8. The answer is 9018, as there must be four figures in the whole number because the index is 3.

3. Mult. 456 .7=2.659631 +

By 97.64=1.989628

Answer . . 44592 4.649259

649237

97) 220 (2

194

26

Here, in seeking the number corresponding to the sum of the logs, we find it to be 445 under 9, taking the next less log. Place this log under our log and subtract. Put a cipher to the right of the remainder and divide by the difference 97, found abreast of log 649237. This gives us 2, the fifth figure wanted for the whole number, because the index is 4. If we wanted another figure we would annex a cipher to the remainder 26 and divide again by the difference 97.

4. Mult. 2300=3.361728 +

By .04371=8.640581

Answer . . 100.5=2.002309

The first index here is 3, because there are four whole numbers. The index of .04371 is 8, because counting the point 1, and 1 nothing make 2, and following the rule, 2 from 10 leave 8. Find the corresponding logs, add them together and seek the number corresponding to this sum 002309. This gives 100 under 5. The indices added with the logs give 12. Subtract 10 from this sum, because we borrowed 10 to get one of them. This leaves 2 for the index, giving three figures in the whole number.

7. *Rule—When either of the numbers to be multiplied is a decimal.* If the tens borrowed are paid back the answer will

be a whole number. If not paid back, the answer will be a decimal.

5. Mult.	.002520=7.401400 +	Log. of 2273=356599	
By	22.7325=1.356647	Corr. for 25=+ 48	
Answer	.05729=8.758047		356647
		Diff.	191
			25
			955
			382
			47.75

The index of .002520 is 7; the point 1, and 2 nothings, make 3, and 3 from 10 leave 7. The index of 22.7325 is 1, because there are two figures in the whole number. When the adding is done, the sum of the indices is 8. We cannot take 10 from this, or *we cannot pay back the 10 we borrowed* to find the first index, and therefore the answer must be all decimals.

To tell where to place the decimal point when the answer is all decimals. Subtract the index from 10 mentally and the remainder will indicate the number the first of the figures taken from the table must be after the decimal point.

EXAMPLES.

1. Multiply 30 by 24.32.
2. Multiply 1456 by 825.
3. Multiply 8108 by .25.
4. Multiply .4127 by .035.

Answers at the end of the Guide.

DIVISION BY LOGARITHMS.

8. In division the logs are taken out the same as in multiplication. Be careful to subtract the log of the divisor from that of the dividend. The number corresponding to the remainder will be the quotient, or answer required.

Remember the rule for taking out the logs for numbers having five or more figures—the first three are found in the left side column, and the fourth at the top. Take out the difference

at the right side column found abreast of the log. Multiply this difference by the remaining figures above four; score off from the right the same number of figures we are correcting for, and add what remains to the log of the first four figures.

If the figures above four are ciphers, no correction is needed. For instance: The log of 347800 is 541330, the same as 3478. The number corresponding to a given log is found the same as in multiplication by logarithms. If required to five or more places of figures, seek in the tables for the log next less than the given log; subtract this from the given log, annex a cipher and divide by the difference found abreast, to the right, in the tables. This gives us one figure. If more are wanted, repeat the operation by annexing a cipher to the remainder and dividing again by the difference as often as necessary.

If you find the log in the tables exactly as required, just annex ciphers to the four figures found for any more figures needed in the answer. Thus, the number corresponding to 6.478855 should be 3012000. Because we find the log exact abreast of 301 under 2, we annex three ciphers to give it seven places, the index being 6.

1. Divide 721 by 44 by common logarithms.

Divide	721	log.	2.857935
By	44	log.	1.643453
Answer .	16.39		1.214482

Here the decimal point is placed so as to have two figures in the whole number, because the index is 1.

2. Divide	7246120 =	6.860105 =	860098	Diff.	60
			7		120
By	8.94 =	0.951337	860105		7,200
Answer .	810528	5.908768			
		908753			
		54) 150 (28			
		108			
		420			

The first number having seven figures, must have six for

its index. The nearest less log corresponding to this log is taken out answering to the first four figures only. The difference in the right-hand column is also taken out and multiplied by the remaining three figures, and, scoring off from the right of the product, also three figures, we have a 7 left, which is added to the log taken out. Thus the log is corrected for figures above four. The second line has one figure in its whole number, and its index is 0. The log of the three figures is taken out as for 894. The lower is subtracted from the upper. Now find the number corresponding to this. The next less log being found and taken from our log leaves 15. The difference found in the right-hand column is 54. We have already taken out four figures of the answer, but we need six, because the index is 5. Annex two ciphers to the 15 and divide by the difference 54; this gives us the other two figures required.

3. Divide	687.4132 =	2.837218		837210	63
By	.63421 =	9.802233	Corr.	+ 8	132
Answer . .	1084	3.034985		837218	396
					792
				802226	
			Corr.	+ 7	8,316
				802233	68
					1
					6,8

In this case the index of 687.4132 is 2, because there are three figures in the whole number, and the index of .63421 is 9, because the decimal point with no cipher next to it counts 1, and 1 from 10 leaves 9. Take the log out for 687 under 4. Multiply the difference 63 from the right side column by 132, the remaining figures; score off the three figures 316, because there were three remaining figures after taking out for the first four. Add the 8 that remains to the log of the first four, and you have the corrected log, .837218. Now, take out the log for 634 under 2, the first four figures, which is .802226, multiply the difference 68 by 1, the remaining figure, which will give you (after scoring off one), 7, to be added, making the corrected log .802233. Now subtract as in the last example, and

you have the log 3.034985. Seek the nearest to this in the tables, and you find 108 under 4, and as the index is 3, the *four* figures just found are placed together, and constitute the answer, which in this case, is a whole number.

9. *Rule for division by logarithms.* If the first number is less than the second, the answer will be a decimal; but if the first number is greater than the second, the answer will be a whole number.

EXAMPLES.

1. Divide 1833 by 39.
2. Divide 629.7 by 12.6.
3. Divide 7571200 by 17.5.
4. Divide 3.6064 by 224.

Answers at the end of the Guide.

PARALLEL SAILING.

10. Parallel sailing is used in navigation to determine the value in difference of longitude of the run the ship has made in nautical miles east or west, called departure, while sailing on a parallel of latitude.

Rule.—To the secant of the Latitude Tables 44 Bowditch, or 25 Norie, *add* the log of the Departure Table 42 Bowditch, or 24 Norie; the sum is the log of the difference of longitude, the number found in the same table.

Always reject 10 from the index when taking out the secant. Remember, too, when using the table of sines, secants, etc., if the degrees are at the top, the names sine, secant, etc., must be taken from the top and the minutes from he left side. If the degrees are at the bottom, the names sine, secant, etc., are found at the bottom and the minutes at the right side.

EXAMPLE.

In latitude 14° 30′, the departure made good was 137

miles. Find the difference in longitude by parallel sailing.

Lat. 14° 30′	Secant (—10)		0.014058 +
Dep. 137	Log.		2.136721
Answer —Diff. Longitude		141.5	2.150779

EXAMPLE—Lat. 50° 24′	Sec.		0.195572 +
Dep. 127.6	Log.		2.105851
Answer —Diff. Longitude		200.2	2.301423

EXAMPLES FOR PRACTICE.

1. Lat. 36° 50′, departure 48 miles; required difference of longitude.

2. Lat. 40°, departure 50.5 miles; required difference of longitude.

3. Lat. 37° 59′ S., departure W. 40.75 miles; required difference of longitude.

4. Lat. 53° 28′, departure 250 miles; required difference of longitude.

Don't forget the rule.—To the log secant of latitude add log of departure. The result is the log of difference of longitude.

Answers at the end of the Guide.

THE DAY'S WORK.

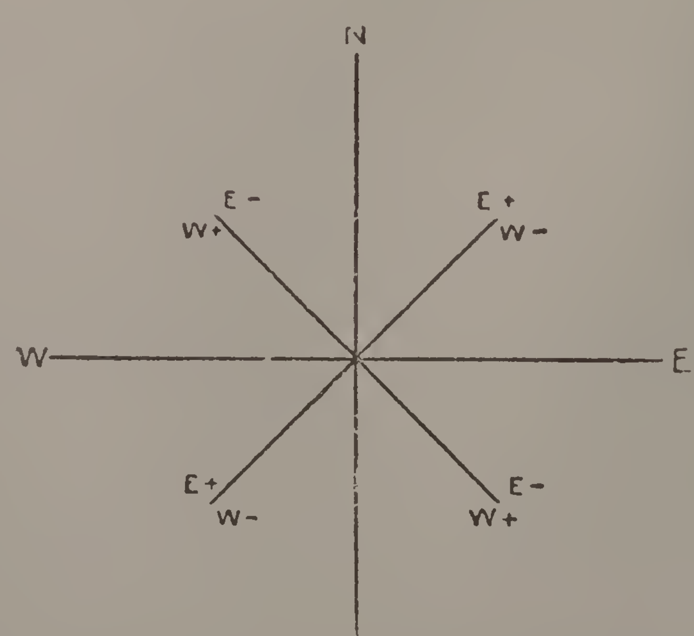
The day's work, so-called, is a means of finding a ship's position at sea after sailing various courses and distances throughout the astronomical day, reckoning from noon till noon. The latitude and longitude left being known, the different courses steered are corrected for leeway, variation and deviation; and any known current is allowed for. The direct course and distance the ship has made good is also ascertained by inspection, or middle latitude sailing.

In correcting courses, always consider yourself at the center of the compass, looking toward the margin at the course to be corrected.

Leeway is of course allowed *from* the wind. To the right, if on the port tack; to the left, if on the starboard tack.

Easterly variation and easterly deviation are allowed to the *right,* and westerly to the *left,* in any quadrant, to find the true course. These may be allowed together, if both are east or west. Or if different names, the least taken from the greater will leave the difference for the correction, to be allowed according to the name of the greater, easterly to the right, westerly to the left. It is well to have a compass card before you while correcting courses, such as is found at the front of this guide. Leeway is usually given in points, and can easily be applied mentally, and the course then turned into degrees by the table of angles, before applying variation and deviation. If the corrected course exceeds 90° subtract from 180° and change its name from north to south, or from south to north as the case may be. Should the correction be larger than the course itself, subtract the course from the correction and change its name from east to west, or from west to east, as the case may be. Never change both sides on one course. Courses should be so arranged as to read from north to east, north to west, south to west, or south to east, so that in the N. E. or S. W. quadrants, correction allowed to the right means add, and to the left subtract; while in the N. W. and S. E. quadrants, correction to the right means subtract and to the left add.

If the variation and deviation are given in points, let the courses remain in points if so given, and use Table 1 in seeking



difference of latitude and departure, instead of Table 2, which is intended for degrees.

The bearing of some known object may be given. This is reversed and called the departure course. The deviation for the direction of the ship's head (usually stated), and the variation are then applied. This is the first course, corrected. Place it in the traverse table with its distance beside it in the proper column.

The other courses are taken (without reversal) and corrected for leeway, variation and deviation. Place these also with their distances, in their proper places in the traverse table.

The current course, if given *magnetic,* must be corrected for variation only; but if given *true,* it requires no correction, but must be placed in the traverse table as the last course, with its given distance beside it.

11. *Difference of latitude and departure.* Take out the difference of latitude and departure for the various courses and distances from Table 2, if degrees, or Table 1, if points, and be careful to give each its proper place in the traverse table, as shown in the examples. Add all the eastings and westings; subtract the least from the greatest, naming the result departure of the same name as the greatest. Add up the northings and the southings, subtract the least from the greatest and name the result difference latitude, same name as the greatest.

Note.—If a distance exceeds the limit of the table in your epitome, seek half the distance and multiply the result by 2 for latitude and departure.

12. *Latitude In.* Turn the difference latitude into degrees (if it exceeds 60′) by dividing by 60, and apply it to the latitude left. If both are north or both south add; if different names, subtract. This gives the *latitude in,* of the same name as the greater.

13. *Middle Latitude.* Add together latitude left and latitude in, if of the same name, N. or S., and divide the sum by 2. The result is the *middle latitude.*

Note—If they have different names, subtract the less from the greater and divide by 2: The result is the middle latitide, same name as the greater.

14. *Difference of Longitude.* Look for the nearest degree of middle latitude as a course, in Table 2, and for the departure, as near as possible, in a latitude column. Abreast of this in the distance column will be found the difference of longitude required; divide by 60, if it exceeds that amount.

15. *Longitude In.* To the longitude left, apply the difference longitude. If both are same name, east or west, add; if contrary names, subtract. This gives longitude in; same name as the greater.

Note.—If the departure exceeds the limit of the table, seek half the departure and multiply the distance found by 2 for the difference of longitude. If the middle latitude happens to be less than 1°, or nothing, use the departure for the difference of longitude. If the longitude by adding exceeds 180° subtract from 360° and name the result contrary to longitude left. This will be *longitude in.* When the middle latitude exceeds 35°, the difference longitude should be found by parallel sailing.

16. *Course and Distance Made Good.* Look for difference of latitude and departure as near as they can be found together in the tables. Take the course from the top of the page if difference of latitude is greater than departure, but from the bottom if departure is greatest. The distance will be found in its own column to the left of difference of latitude and departure. Name the course same as difference of latitude and departure.

Notes.—If difference of latitude is nothing, the course must be east or west, same as departure; and the distance same number of miles as departure. If the departure is nothing, the course is north or south, same as difference of latitude, and the distance same number of miles as difference of latitude.

EXAMPLES.

	Hours	Courses	Knots	Tenths	Winds	Leeway	Remarks, Etc.
Bearing ENE	1	SW	6	5	S SE	½pt	Cape Flattery,
Reversed—WSW	2		6	5			in lat. 48° 23'
S 6 pts W	3		6				N, and long.
Var. 2 pts E	4		6				124° 44' W.
1. S 8 pts W	5		6	4			Bearing E N
	6		6	6			E magnetic.
Pts.	7	W SW	5		South	1 pt	Dis. 7 miles.
S 4½ W	8		5				
Var. 2 E	9		5				
2. S 6½ W	10		5				
	11		4				
S 7 W	12		4				
Var. 2 E	1	ExS ½S	5		S ½ E	½pt	Var. 2 points
9	2		5				easterly.
16	3		5				
3. N 7 W	4		5				
	5		5				
S 7 E	6	SExS ½S	9	5	NW	0	A current set
Var. 2 E	7		9	5			N W true 6
4. S 5 E	8		10	5			miles.
	9		10	5			
S 2½ E	10	S SE	10		NW	0	
Var. 2 E	11		10				
5. S ½ E	12		9				

S 2 E
Var. 2 E
6. 0 = S
7. NW true=N 4W

Correct the courses for Variation and Leeway and find the ship's position; also course and distance made good.

NOTE — The leeway has been allowed mentally in the work before you.

Lat. left 48° 23' N
Lat. in 46° 59' N
2) 95.22
Mid.lat. 47° 41'

Dep. 50.4 = Diff. long. 75' W
1° 15' W

Corrected Courses	Dist	Diff N	Lat S	Departure E	W
West	7	..	..	..	7.0
S 6½ W	38	..	11.0	..	36.4
N 7 W	28	5.5	..	..	27.5
S 5 E	25	..	13.9	20.8	..
S ½ E	40	..	39.8	3.9	..
South	29	..	29.0	..	..
N 4 W	6	4.2	..	..	4.2
		9.7	93.7	24.7	75.1
			9.7		24.7

Diff. Lat. 60 | 84. 0 Dep. 50.4W
1° 24' S

Lat. left 48 23 N
Lat. in 46° 59' North

Long. left 124° 44' W
Diff. long. 1 15 W
Long. in 125° 59' W

Course S 31° W; Distance 98 miles

	Hour	Courses	Knots	Tenths	Wind	Leeway	Dev.	Remarks, etc.
S 2½ E=S 28° E	1	S S E	6	5	SW	½pt	3°W	
Error 19° E	2		6	5				Lat. left
1. S 9° E	3		6					46° 10' N
S 5 E=S 56° E	4		6					
Error 17 E	5		6					Long. left
2. S 39 E	6	S E	5		S SW	1	5°W	125° 14' W
	7		5	4				
S 3½ E=S 39° E	8		5	6				
Error 18 E	9		5					
3. S 21 E	10	SE×S	6		SW×S	½	4°W	
	11		6					Var. 22° E
S 3¾ W=S 42° W	12		6	5				
Error 26 E	1		7	5				
4. S 68 W	2		7					
	3	SW½ S	7		SE×S ½S	¼	4° E	
S 2¼ W=S 25° W	4		7					
Error 24 E	5		8					
5. S 49 W	6		8					
	7		5					
N 6 W=N 67° W	8	S×W½ W	5		SE½ S	¾	2° E	
Error 22 E	9		5					Current W NW
6. N 45 W	10		5					Magnetic
	11		5					12 miles
	12		4					

The courses are corrected mentally for leeway and then turned into degrees. The variations and deviations are added together when of same name, and the least subtracted from the greatest when of different names; the result is the error, and is named the same as the greater and applied accordingly,

Latitude, left, 46° 10' N
Latitude, in 44 32 N
2) 90 42
Mid. latitude 45 21

True Course	Dists.	Diff. Lat. N	Diff. Lat. S	Departure E	Departure W
S 9° E	31	......	30.6	4.8	.....
S 39 E	21	......	16.3	13.2	.....
S 21 E	33	......	30.8	11.8	.....
S 68 W	35	......	13.1	......	32.5
S 49 W	24	......	15.7	......	18.1
N 45 W	12	8.5	......	......	8.5
		8.5	106.5	29.8	59.1
			8.5		29.8

Dep. 29.3=diff. Long. 41' W

Diff. lat. 60)98.0 Dep. 29.3 W=41
1° 38' S

Course made good, S 17° W
Distance, 103 miles.

Lat. left 46 10 N
Lat. in 44° 32' North

Long. left 125° 14' W
Diff. long. 41' W
Long. in 125° 55' West

Hours	Courses	Knots	Tenths	Wind	Leeway	Dev	Remarks, Etc.
1	NE×N	7		NW×N	¼pt	4°W	A point in lat. 19° 15' North long. 167°45' E, bearing by comp. S. ½ E, distant 10 miles; ship's head NE×N. Dev. as per log 4° W.
2		7					
3		6					
4		6					
5	NE	7	2	N NW	½pt	5°W	
6		7	4				
7		7	4				
8		8					
9	NW×N	7	5	W×S	0	6°E	
10		7	5				
11		8					
12		8					
1	NW×W	7	5	SW×W	¾pt	5°E	Var. 15° E
2		7	5				
3		8					
4		6					
5	East	7	6	N NE	1	8°W	A current set N NW
6		7	4				
7		7					
8		7					
9	E NE	6	4	North	½pt	9°W	Correct mag. 36 miles.
10		6	4				
11		6	6				
12		6	6				

Bearing S½E revrs'd
=N½W=N 6°W
Var. 15 E
N 9 E
Dev. 4 W
1. N 5 E

N 37° E
Var. 15 E
N 52 E
Dev. 4 W
2. N 48 E

N 51° E
Var. 15 E
66
Dev. 5 W
3. N 61 E

N 34°W
Var. 15 E
19
Dev. 6 E
4. N 13 W

N 48°W
Var. 15 E
33
Dev. 5 E
5. N 28 W

S 79° E
Var. 15 E
64
Dev. 8 W
6. S 72 E

N 73° E
Var. 15 E
88
Dev. 9 W
7. N 79 E

N 23°W
Var. 15 E
8. N 8 W

Correct the courses mentally for leeway and convert into degrees. The var. and dev. are here allowed separately. The first correction for the first course is more than the course, so we subt. the course from the correction and change the name of the course to East.

True Course	Dists.	DIFF. LAT. N	DIFF. LAT. S	DEPARTURE E	DEPARTURE W
N 5° E	10	10.0	......	0.9	......
N 48 E	26	17.4	......	19.3	......
N 61 E	30	14.5	......	26.2	......
N 13 W	31	30.2	......	.....	7.0
N 28 W	29	25.6	.....	......	13.6
S 72 E	29	......	9.0	27.6	.....
N 79 E	26	5.0	......	25.5	.....
N 8 W	36	35.6	......	......	5.0
		138.3	9.0	99.5	25.6

9.0 25.6

Diff. Lat. 60)129.3 Dep. 73.9 E= 6.0)7.9
2°09' N 1°19' E

Lat. left 19 15 N Long. left 167 45 E

Course made good N 30° E. Lat. in 21°24' N Long. in 169°04' E

Distance 149 miles. 2) 40°39'

Mid. lat. 20 19

EXAMPLE FOR PRACTICE—No. 1

Correct the courses for Variation and Leeway, and find Latitude and Longitude in; also the course and distance made good by Inspection.

Hours	Courses	Knots	Tenths	Wind	Leeway	Remarks, etc.
1	N NE	4	7	East	1 pt.	
2		4				
3		4	3			A point in
4		4				Lat. 38° 16' N
5	N×E	4		E×N	½	Long. 15° 14' E
6		4	7			Bearing South
7		4	8			Mag.; Dist. 6
8		4	5			miles.
9	SW	5	6	S SE	2	
10		5	4			
11		5	7			
12		5	3			
1	W SW	6	6	South	1½	Var. 2 pts. W.
2		6	2			
3		6				
4		6	2			
5	West	6	6	N NW	1	
6		6	7			
7		6	8			
8		5	9			
9	South	6	7	W SW	½	Current set
10		6	8			N NW Mag.
11		7	1			28 miles
12		7	4			

EXAMPLE FOR PRACTICE—No. 2

Correct the courses for Leeway, Variation and Deviation, and find Latitude and Longitude; also true course and distance made good by Inspection.

Hours	Courses	Knots	Tenths	Wind	Leeway	Devia.	Remarks, etc.
1	NW×N	7	3	NE×N	½ pt	0°	A point in
2		7	4				Lat. 40° 20' N
3		7	3				Long. 125° 20' W
4		7					bearing by
5	NW	7	6	N NE	1	3° E	Compass
6		7	7				E×N ⅛N
7		7	4				Ship's head
8		8	3				NW×N
9	W NW	8	5	North	½	11° E	Deviation as
10		8	5				per log 0°
11		8					Dist. 5 miles
12		8					Var. 16° E.
1	NW×W	8		N×E	¼	7° E	
2		8					Current NW
3		8	3				Mag. 30 miles
4		7	4				
5	S×W	7	6	SE×E	0	14° E	
6		7	7				
7		7	4				
8		7	6				
9	S SW	7	4	SE	½	23° E	
10		7	2				
11		7	4				
12		7					

EXAMPLE FOR PRACTICE—No. 3

	Hours	Courses	Knots	Tenths	Wind	Leeway	Remarks, etc.
Correct the courses for Leeway and Variation, and find ship's position; also course and distance made good.	1	N×E	6	5	NW×W	1 pt.	
	2		6	5			
	3		6				A point in
	4		6				Lat. 50° 29′ S.
	5	North	6		W NW	½	Long. 59° 20′ W
	6		6				Bearing W×S
	7		7				Magnetic;
	8		7				Distance
	9	N NW	8		West	1	12 miles
	10		8				
	11		8	6			
	12		8	4			
	1	E×S	7	6	NE×N	1¼	Var. 2 pts. E.
	2		7	6			
	3		7	4			No deviation.
	4		7	4			
	5	SE	7		E NE	1	Current set
	6		7				North correct
	7		6				Mag. 24 miles
	8		6				
	9	SW	6		S SE	1½	
	10		6				
	11		5				
	12		5				

Answers at the end of the Guide.

ALTITUDE BY SUN'S MERIDIAN ALTITUDE.

The sun's declination should be corrected for the approximate longitude of the ship by Table 21, Norie, or other table for that purpose. If this is not done, the declination must be corrected by the variation in 1 hour for the hours and tenths of an hour of the Greenwich date, for, remember, the declination, like other Nautical Almanac data, is given for noon at Greenwich.

17. *To Find the Greenwich Time.* Put down the date and 0 h 0 m 0 s. This is apparent noon at ship. Turn the longitude into time by multiplying by 4 and dividing by 60; or use Table 7, Bowditch, or 19 Norie. If west longitude add to apparent time at ship; but if east, subtract from apparent time at ship. We now have apparent time at Greenwich. When the longitude in time is east to be subtracted, borrow 24 hours and call the date one day less.

18. *Correct the Declination.* Take out the declination and the variation in 1 hour from page 1 of the month, Nautical Almanac, for the Greenwich date. Multiply the hourly variation by the hours and tenths of an hour in the Greenwich time, and the result is the correction for the declination, to be added if declination is increasing, but subtracted if declination is decreasing.

It is best to take out declination for nearest noon and work the corrections backwards, as in the following example, where the hours exceed 12.

EXAMPLE.

	d.	h. m. s.		Decl. N. Decr.		Var. in 1 hour.
A. T. Green. Aug.	7	19 44 12	Aug. 8	16° 12' 47"		42".45
		24	Corr.	+ 3 3		4 3
Time from Noon		4 15 48	Decl.	16 15 50	N.	12735
						16980
						6,0) 18,2.535
						3 03

Note.—In the above example, although the declination is decreasing, the correction is added because we are working back from nearest noon. The tenths of an hour are found by dividing the minutes by 6. After multiplying variation in 1 hour by the hours and tenths, score off from the right as many figures as there are decimals, and divide the rest by 60 to reduce them to minutes, if necessary. When declination for Greenwich day and day following have different names, call the declination decreasing, and the correction subtractive. If the correction is less than the declination, subtract the correction from the declination, and give the result same name as the declination; but if the correction is greater than the declination subtract the declination from the correction and name contrary to the declination.

19. *Find True Altitude.* To the observed altitude apply index error, if any; add if +; subtract if —; dip for height of eye, found in Table of Dip, always subtract (14 Bowditch; 5 Norie); sun's correction (refraction and parallax) Table 18 Norie, always subtract; sun's semi-diameter from page 2 Nautical Almanac, for the day given in the example; lower limb add, upper limb subtract. The result is the true altitude.

20. *Zenith Distance.* Subtract the true altitude from 90° 0′ 0″, and name the result zenith distance, contrary to the bearing of the sun as given in the example.

Note: If the true altitude exceeds 90deg., subtract 90deg. and name the result Zenith Distance same name as sun's bearing.

21. *Find the Latitude.* Under the zenith distance place the sun's corrected declination, with its name N. or S.; add these two together if of the same name; subtract if different names. We now have the latitude, always of the same name as the greater.

Note.—Table 9, Norrie, gives one correction for an altitude of the sun's lower limb, including dip, refraction, parallax and sun's semi-diameter. The result is very close to the truth, though it may differ a few seconds of arc from the above more elaborate method of using many tables.

EXAMPLE 1.

1900. June 3rd; longitude 140° W.; observed meridian altitude of the sun's lower limb 60° 13′ 30″ bearing S.; index error + 0′ 30″; height of eye 28 feet. Required the latitude.

	Green. Time. d. h. m. s.	Long.	Decl. N. Incr. d.		Var. in 1 Hour.
A. T. S.	June 3 0 0 0	140° W	June 3	22° 17′ 44″	18″.7
Long. in Time	+9. 20. 0	4	Corr.	+ 2 54	9 .3
		6,0)56.0	Corr. Decl. 3d	22.20.38 N	561
A. T. Green.	3d 9 20 0	9 h. 20 m			1683
					6,0) 17,3.91
					2′ 54″

Obs. Alt.	60° 13′ 30″ S.
I. Error	+ 30
	60 .14 .00
Dip	— 5 11
	60 08 49
Sun's Corr.	— 29
	60 08 20
Semidia.	+ 15 47
True Alt.	60 24 07 S.
	90 00 00
Zen. Dist.	29 35 53 N.
Corr. Decl.	22 20 38 N.
Latitude	51° 56′ 31″ N.

SHORT METHOD.

Alt.	60° 13′ 30″ S
I. E.	+ 30
	60 .14 .00
Table 9 Norie	+ 10 .00
True Alt.	60 .24 .00 S.
	90 0 0
Z. Dist.	29 36 0 N.
Decl.	22 20 38 N.
Latitude	51 .56 .38 N.

Note.—The difference is but 7 seconds of arc. The style is all right, and is used every day at sea on ocean greyhounds.

EXAMPLE 2.

1900, January 29th; longitude 173° 05′ E; observed meridian altitude sun's upper limb 22° 48′ 40″ bearing S; index error — 1′ 20″; eye 26 feet. Required the latitude.

	d. h. m. s.	Long. E		Decl. S. Decr.	H. Var.
A. T. S. Jan.	29 0 0 0	173° 5'	Decl.	18° 14' 13'' S	39''.5
		4			
Long. in Time	—11 32 20	6,0)69,2.20	Corr.	— 8 14	12 5
A. T. Green.	28.12.27.40	11.32.20	C. Dec.	18.05 59 S	1975
					4740
					6,0)49,3.75
					8' 14''

The declination is taken out for the 28th, and corrected by its hourly variation for 12 hours and 5 tenths. The longitude in time here is subtracted from ship's time because the longitude is east.

Obs. Alt.	22° 48′ 40″	S.
I. E.	— 1 20	
	22 .47 .20	
Dip.	— 5	
	22 .42 .20	
Corr. T. 18 Norie.	— 2 8	
	22 .40 .12	
Semi. dia. U. L.	— 16 .16	
True Alt.	22 .23 .56	S.
	90 0 0	
Zen. Dist.	67 .36 .04	N.
Corr. Decl.	18 .5 .59	S.
Latitude	49 .30 .05	North.

The semi-diameter in this case has been *subtracted,* because the sun's *upper* limb was observed.

EXAMPLE 3.

1900, April 11th; longitude 48° W.; observed meridian altitude sun's lower limb 38° 5′ 35″ bearing N.; eye 21 feet; index error + 1′ 26″. Required the latitude.

	d. h. m. s.		Decl. N. Incr.	H Var.
A. T. S. Apr.	11 0 0 0	48° W	8° 15' 11"	55".1
	+ 3 12 0	4	2 56	3 .2
	d. h. m. s.	6,0)19,2	Cor. Decl. 8° 18' 07" N	110 2
A. T. Green.	11 3 12 0	3 12		1653
				6,0)17,6.32
				2' 56"

Obs. Alt.	38° 5′ 35″ N.
I. E.	+ 1 26
	38 .07 .01
Corr. T. 9 Norie.	+ 10 .21
T. Alt.	38 .17 .22 N.
	90 0 0
Z. Dist.	51 .42 .38 S.
Decl.	8 18 7 N.
Latitude	43 .24 .31 South.

One correction from Table 9 Norie has been used in correcting this altitude.

EXAMPLES FOR PRACTICE.

1. 1900, February 27th; longitude 150° 45′ E.; observed meridian altitude sun's lower limb 50° 6′ 35″ N.; eye 24 feet; index error — 1′ 40″. Required the latitude.

2. 1900, January 17th; longitude 127° 40′ W; observed meridian altitude sun's upper limb 50° 35′ 35″ N.; eye 28 feet; index error — 1′ 30″. Find the latitude.

3. 1900, August 7th; longitude 36° E.; observed meridian altitude sun's lower limb was 62° 34′ 55″ S.; eye 25 feet; index error + 25″. Required the latitude.

4. 1900, June 4th; longitude 178° 50′ W.; observed meridian altitude sun's lower limb 69° 20′ 45″ N.; eye 29 feet; index error — 1′ 7″. Required the latitude.

5. 1900, October 13th; longitude 114° 59′ E.; observed meridian altitude sun's lower limb 61° 9′ 45″ S.; eye 24 feet; index error — 2′ 10″. Required the latitude.

Answers at the end of the Guide.

MERCATOR'S SAILING.

This is a method of finding the true course and distance between any two places, A and B, by calculation on Mercator's principle.

22. *To Find Difference of Latitude.* If latitudes are different names, add them together; but if the same name, subtract the less from the greater, and bring the result to miles by multiplying the degrees by 60 and adding in the minutes. Call this difference of latitude north or south, as the place bound to is north or south of the place from.

23. *Meridional Difference of Latitude.* Take out meridional parts for both latitudes from Table 3 Bowditch or Norie; degrees at the top, minutes at the side of table. Latitudes different names, add the meridional parts; latitudes same name, subtract the least from the greatest, and name the result meridional difference latitude.

24. *Difference of Longitude.* Longitudes contrary names, add them together; longitudes same name, subtract the least from the greatest. Turn the result into miles by multiplying the degrees by 60 and adding in the minutes. Name this difference of longitude, east or west, as the place to is east or west of the place from.

When, with longitudes contrary names, the sum exceeds 180°, subtract from 360°, then reduce to miles; *but in this case* name it difference of longitude east or west, *same as longitude left.*

25. *To Find the Course.* From log difference of longitude, Table 42 Bowditch, or Table 24 Norie, *subtract* log *meridional* difference of latitude, same table, and look up the *tangent* of the remainder in Table 44 Bowditch, or Table 25 Norie. This is the *course,* to be named according to the difference of latitude and difference of longitude. Always add 10 to the index of the log of difference of longitude.

26. *To Find the Distance.* To the log secant of the course (same table as the tangent) *add* log difference of lati-

tude, Table 42 Bowditch, or 24 Norie, and take out the number corresponding to their sum from the same table. This will be the *distance*. Always substract 10 from the index of the secant of the course.

Always name the course according as the ship is making northing or southing, and easting or westing; express the course in degrees and minutes.

Note.—When the sum of longitudes contrary names has been taken from 360°, name the course same as longitude left.

EXAMPLE.

Required the course and distance from Cape Flattery, in latitude 48° 23′ N. and longitude 124° 44′ W., to the eastern extreme of Oahu island, near Honolulu, in latitude 21° 18′ N. and longitude 157° 39′ W.

C. Flattery Lat. 48° 23' N.	Mer. Pts...... 3309	Long...... 124° 44' W.
Oahu Is. Lat... 21 18 N.	Mer. Pts...... 1300	Long...... 157 39 W.
27 .5	Mer. Diff. Lat. 2009	32 .55
60		60
Diff. Lat..... 1625 South.		Diff. Long. 1975 West.

For the Course.		For the Distance.	
Diff. Long. 1975 Log. +10=	13.29557	Course, 44°31' Secant—10=	0.14688
Mer. Dif. Lt. 2009 Log.	= 3.30298 —	Dif. Lt. 1625 Log.	=3.21085 +
Course S. 44°31' W. Tang.	= 9.99259	Distance, 2,279 Miles,	=3.35773

Course S. 44° 31′ 00″ W.; distance 2,279 miles.

EXAMPLE.

Find the course and distance from Cape Bealle, in Lat. 48° 48′ N. and Long. 125° 14′ W., to a position off Unimak Pass, in Lat. 53° 40′ N. and Long. 164° 0′ W.

Cape Bealle, Lat... 48°48' N.	Mer. Pts...... 3364	Long...... 125°14' W.
Unimak Pass, Lat. 53.40 N.	Mer. Pts...... 3831	Long...... 164 .0 W.
4.52	Mer. Diff. Lat. 467	38.46
60		60
Diff. Lat........ 292 North.		Diff. Long. 2326 West

For the Course.		For the Distance.	
Diff. Long. 2326 Log. +10=	13.366610	Course, 78°39' Sec. —10=	0.705971
Mr.Dif.Lat. 467 Log.	= 2.669317 —	Diff. Lat. 292	=2.465383 +
Course N. 78°39' W. Tang.	=10.697293	Distance, 1484 miles,	=3 171354

Course N. 78° 39′ W.; distance 1,484 miles.

Note.—Tables 3 in Bowditch and Norie do not give exactly the same meridional parts, and as these Mercators are worked from Norie, some difference will be found if Bowditch is used. The first example is worked by Bowditch.

EXAMPLE.

Required the true course and distance from Sierra Leone to Cape Branco by calculation on Mercator's principle.

Lat. Sierra Leone,	8° 31' N.	Mer. Pts......	513	Long......	13° 16' W.
Lat. C. Branco ...	7 .8 S.	Mer. Pts......	429	Long......	34 .48 W.
	15 .39	Mer. Diff. Lat.	942		21 .32
	60				60
Diff. Long......	939 South.			Diff. Long.	1292 West.

Diff. Long... . 1292	.13.111262 −	Course, 53° 54'½	.0.229827	+
Mer. Diff. Lat.. 942	.2.974051	Diff. Lat.....939	.2 972666	
Course S. 53° 54'½ W.	10.137211	Dist. 1594 miles,	.3.202493	

EXAMPLE.

Required the true course and distance from Otago to Callao by calculation on Mercator's principle.

Lat. Otago......	45° 46' S.	Mer. Pts......	3095	Long......	170° 38' E.
Lat. Callao......	12 .4 S.	Mer. Pts......	729	Long......	77 .5 W.
	33 .42 N.	Mer. Diff. Lat.	2366		247 .43
	60				360 .00
Diff. Lat......	2022 Miles.				112 .17 E.
					60
				Diff. Long....	6737 Miles.

Diff. Long. 6737....	.13.828467 −	Course 70° 39'	.0.479729	+
Mer. Diff. Lat. 2366,	.3.374015	Diff. Lat. 2022	.3.305781	
Course N. 70° 39' E.	.10.454452	Distance 6102 miles,	.3.785510	

EXAMPLES FOR PRACTICE.

1. Find true course and distance from A to B. Lat. A, 36° 35 S.; Long., 34° 35′ W. Lat. B, 48° 49′ S.; Long., 30° 11′ W.

2. Required true course and distance from A to B. Lat. A, 9° 36′ N.; Long., 20° 36′ W. Lat. B, 13° 36′ S., Long. 7° 56′ E.

3. Find true course and distance from A to B. Lat. A,

13° 17′ N.; Long., 59° 24′ W. Lat. B, 8° 48′ S.; Long., 13° 14′ E.

4. Required true course and distance from A to B. Lat. A, 42° 51′ N.; Long., 124° 30′ W. Lat. B, 52° 58′ N.; Long., 172° 17′ E.

Answers at the end of the Guide.

AMPLITUDE.

Compass Error and Deviation by Sun's Amplitude.

The apparent time at ship, latitude, longitude east or west, the observed compass amplitude, and the variation are usually given in the question.

If apparent time at ship is P. M., write down the date and time as given; but if apparent time at ship is A. M., add 12 to the hours and call the date one day less.

Find the Greenwich Time. To the apparent time at ship, as now stated, apply the longitude in time; west longitude, add; east longitude, subtract; the result is apparent time at Greenwich.

Notes.—The longitude is turned into time by multiplying by 4 and dividing by 60; or we may use Table 7 Bowditch or 19 Norie, for this purpose. When the longitude in time west, added to apparent time at ship exceeds 24 hours, subtract 24 hours and call the date one day more. When the longitude in time east, to be subtracted, is greater than the hours, minutes and seconds of the apparent time at ship, add 24 hours to the apparent time at ship and make the date one day less.

Declination for the Greenwich Time. Take out the declination from page 1 of the month for the Greenwich day, also the variation in 1 hour, found beside the declination. Multiply this hourly variation by the hours and tenths of an hour of the Greenwich time, and we have the correction for the declination, to be added if the declination is increasing, and subtracted if the declination is decreasing. Thus we have the declination corrected for the Greenwich time.

Note.—When the declination on the following day is of a different name, the declination is decreasing. In this case, if the correction to be subtracted is greater than the declination, subtract the declination from the correction and name the result contrary to the declination. If the correction is less than the declination, subtract the correction from the declination and name the result corrected declination, the same name, north or south, as the declination.

27. *Find the True Amplitude.* To the log secant of the latitude (10 subtracted from the index), add the log sine of the corrected declination; the result will be the log sine of the true amplitude.

All the logs are found in Table 44 Bowditch or 25 Norie.

28. *Name the True Amplitude.* Name it from east if A. M., from west if P. M. at ship; towards north or south, according as corrected declination is north or south.

29. *Error of the Compass.* Right under the true amplitude as found, place the compass amplitude given in the question. If both are north or south subtract the least from the greatest; but if contrary names, add them together. The result is the error.

Notes.—If the compass amplitude as given in the example is not reckoned from the same point east or west as the true, subtract the compass amplitude from 180° and change it to east or west, the same as the true amplitude. Do not neglect this, for both amplitudes must be reckoned from the same point east or west. If the declination is 0° 0′ the true amplitude is E. 0° 0′ if A. M. and W. 0° 0′ if P. M. If the latitude is 0° 0′ the true amplitude is the same as the declination.

30. *Name the Error.* Consider yourself at the center of the compass looking toward the point east or west from which the amplitudes are reckoned. Now, if the *true* is to the *right* of the compass amplitude, the error is east; but if the *true* is to the *left,* the error is west.

31. *To Find the Deviation.* Place the variation given in the example under the compass error, and if they are both east or both west, subtract the least from the greatest; but if con-

trary names, add them together. The result is the deviation.

32. *Name the Deviation.* When error and variation have contrary names, name the deviation same as the error. When error and variation have same name, name the deviation same as the error if the error is greatest; but contrary to the error if the variation is greatest. *Commit this rule to memory. It will save you much worry.*

Notes.—If the error is 0°, the deviation will be the same as the variation, but of a contrary name. If the variation is 0°, the deviation is same as the error and of the same name.

EXAMPLE 1.

1900, October 7th 7 h 10 m P. M. apparent time at ship; latitude 40° 29′; longitude 37° W.; sun's compass amplitude, W. 14° 21′ S. Required the compass error.

A. T. S..........	7d	7h	10m
Long. in T....	+	2	28
A. T. G.........	7	9	38

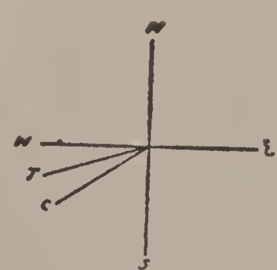
Long. 37° W.
4
6,0)14,8
2h 28m

Decl. S. increasing	5°	25′	49″	
Corr. +		9	12	
Corr. decl.	5	35	01	S

Hourly Var.
57″.5
9 .6
3450
5175
6,0) 55,2.00
9′ 12″

Lat..	40° 29′	Secant—10 =	0.118847+
Corr. Decl..	5° 35′	Sine	8.988083
			9.106930

True Amp.......................	W 7° 21′ S
Comp. Amp...................	W 14 21′ S
Error.........	7° 00′ East



In the above example no variation is given, so that no deviation is called for. The true amplitude is west, because it is P. M., and south, because the corrected declination is south. The least amplitude is subtracted from the greatest, because they are the same name, both south. The error is named *east,* because the *true* amplitude is to the *right* of the compass amplitude, when looking towards them from the center of the compass.

EXAMPLE 2.

1900, March 9th 5 h 20 m 19 s A. M. apparent time at ship; Lat. 39° 40′; Long. 150° 12′ E.; sun's compass ampli-

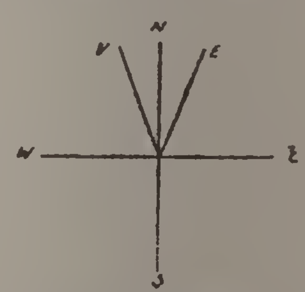
tude E. 2° 45′ S.; variation 3° 10′ W. Required the error of compass and the deviation.

A. T. S.........	8d 17h 20m 19s	Long. 150°12′ East	Decl. S. decreasing.	H. Var.
Long. in T...	— 10 .00 .48	4	4° 56′ 50″	58″.45
A. T. G........	8d 7 .19 .31	6,0) 60,0.48	Corr. — 7 .07	7.3
		10 .00 .48	Corr. decl. 4 .49 .43 S	17535
				40915
				6,0) 42,6.685
				7′ .7″

Lat......	39°40′	Sec.—10=0.113638	-/-
Corr. Decl.	4 49½	Sin.	=8.924861
True Amp.	E 6°16′30″ S.		=9.038499
Comp. Amp.	E 2.45.00 S.		
Error	3.31.30 E.		
Var.	3.10.00 W.		
Deviation	6°41′ 30″ East.		

This example is worked out to nearest half minute of arc, as near as the examination calls for. The time being A. M., 12 is added to the hours and the date made one day less. The longitude in time is subtracted from apparent time at ship, because it is east. The true amplitude is reckoned from east because it is A. M. Towards south because the corrected declination is south. The least amplitude is subtracted from the greatest because they are same name, south. The error is named E., because the *true* amplitude is to the *right* of the compass amplitude. The error and variation are added because they are different names, east and west. The deviation is named east like the error, because the error and variation have contrary names.

Note.—The name of the deviation can also be found by marking off the error and variation at the north point of the compass, thus—



E. representing error and V. the variation. *Easterly* error is marked off to the *east* of N. and *westerly* variation is marked off to the *west* of N., shown by the adjoining compass. Now, the error being to the *right* of the variation the deviation is *east*. If the errror had been to the *left* of the variation, the deviation would have been *west*.

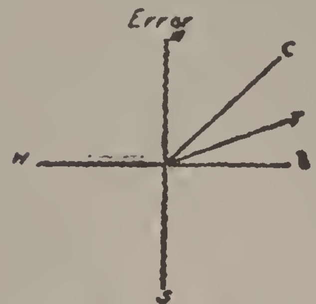
EXAMPLE 3.

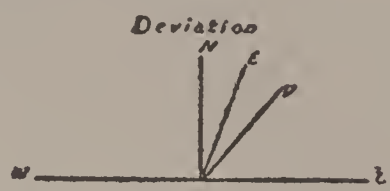
1900, July 3rd, 3 h 20 m 35 s A. M., apparent time at ship; Lat. 49° 49′; Long. 167° 15′ W.; sun's compass ampli-

tude **N. E. ½ E.**; variation 12° 50′ E. Find the error and deviation.

A. T. S.......2d 15h 20m 35s	Long, 167°15′ W	Decl. N. decreasing	H. Var.
Long in T. + 11 9	4	22°59′24″	11″.86
A. T. G.... 3d .2 .29 .35	6,0)66,9.00	Corr. — 30	2.5
	11 h 09 m	Corr. Dec. .22.58.54 N.	5930
			2372
			29.650

Lat......49°49′ Sec. 0.190282
Decl.....22 59 Sin. 9.591580 +
T. Amp....E37°14½ N.= 9.781862
C. Amp.... E39.22½ N.
Error....... 2.08 E.
Var......... 12.50 E.
Dev......... 10°42′ W.





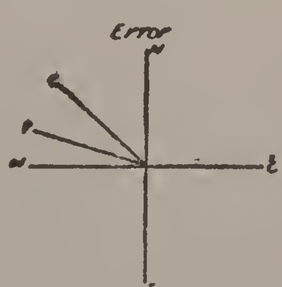
Here again, the time being A. M., 12 is added to the hours and the date put back one day. The longitude in time, west, added, makes it exceed 24 hours, so we reject 24 and call the date one day more. The true amplitude is E., because the time is A. M., and N., because the corrected declination is north. The compass amplitude N. E. ½ E. = E. 3½ points. N. = E. 39° 22′ 30″ N. The error is E., because the true amplitude is to the right of the compass amplitude. The deviation is W., because the error is to the left of the variation; or, using the other rule, because the error and variation have the same name, but the variation is greater than the error.

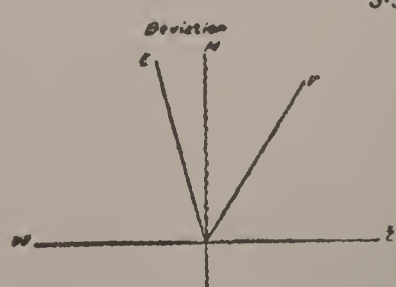
EXAMPLE 4.

1900, September 20th, 6 h 0 m 0 s P. M., apparent time at ship; Lat. 23° 15′; Long. 146° 05′ E.; sun's compass amplitude W. ¼ N.; variation 10° 55′ E. Required error and deviation.

A. T. S. 20d 6h 0m 0s	Long. 146° 5′ E.	Decl. N. decr.	H. Var.
Long. in T...... — 9 .44 .20	4	Sept. 20, 1° 10′ 25″	58″.3
A. T. G ....19d 20 .15 .40	6,0)58,4 .20	Corr. + 3 .36	3.7
24	9h 44m 20s	Corr. decl. 1 .14 .01 N	4081
			1749
T. from Noon 20d 3 .44 .20			6,0)21,5.71
			3.36

Lat............ 23° 15′ Sec. 0.036783 +
Decl........... 1 14 Sin. 8.332924
T. Amp. W. 1° 20′N. Sin. 8.369707
C. Amp. W. 2 48 45 N.
Error......... 1 28 45 W.
Var............ 10 55 00 E.
Dev........... 12 23 45 W.





Here the longitude in time east to subtract exceeds the

time at ship, so we borrow 24 hours and make the date one day less; but we have taken the declination out for the 20th, the nearest noon at Greenwich, and worked backwards 3 hours and 7 tenths, applying the correction for the declination the opposite way. The tenths are found by dividing the minutes of the Greenwich time by 6. Name true amplitude from W. because it is P. M.; towards N. because declination is north. The difference between the amplitudes is taken for the error because they are same name, both north. The error is W. because the true amplitude is to the left. The error and variation having contrary names, are added to find the deviation, and, *when error and variation have contrary names, name the deviation same as the error.*

EXAMPLES FOR PRACTICE.

1. 1900, August 17th 5 h 38 m 29 s P. M., apparent time at ship; Lat. 22° 56′ S.; Long. 23° 35′ W.; sun's compass amplitude W. 20° 30′ N.; variation 10° W. Required compass error and deviation.

2. 1900, September 15th 5 h 59 m 30 s A. M., apparent time at ship; Lat. 44° 1′ S.; Long. 144° 17′ E.; sun's compass amplitude E. 5° 49′ S.; variation 10° 5′ E. Required compass error and deviation.

3. 1900, October 4th, 6 h 16 m 10 s A. M., apparent time at ship; Lat. 24° 59′ N.; Long. 160° 5′ W.; sun's compass amplitude E. 11° 27′ N.; variation 12° E. Required compass error and deviation.

4. 1900, July 23rd, 7 h 27 m 50 s P. M. apparent time at ship; Lat. 49° 29′; Long. 177° 59′ E.; sun's compass amplitude W. 23° 30′ N.; variation 12° E. Required compass error and deviation.

5. 1900, November 6th, 7 h 33 m 06 s P. M., apparent time at ship; Lat. 43° 28′ S.; Long. 123° 34′ E.; sun's compass amplitude W. by S $\frac{1}{2}$ S.; variation 8° 30′ W. Required compass error and deviation.

Answers at the end of the Guide..

LONGITUDE BY CHRONOMETER.

33. *Mean Time at Greenwich.* Apply the given error to the chronometer time; add if slow; subtract if fast. Then apply the accumulated rate, add if losing, subtract if gaining; and the result is the mean time at Greenwich, expressed. M. T. G. The accumulated rate is found by multiplying the daily rate by the days and tenths of a day that have elapsed since the chronometer error was found, till the time as now shown by the chronometer with its original error applied. The tenths of a day are found by dividing the hours and tenths of an hour of the chronometer time, after the error is applied to it by 24. (47.) Tenths of an hour are found by dividing the minutes by 6.

Suppose we have 6 h 54 m. The 54 m divided by 6 gives 9 tenths; thus we have 6.9 h, and 69 divided by 24 gives 3 nearly, or 3 tenths of a day.

Sometimes, in the examples, the daily rate is not given, but the chronometer errors are stated for two given dates. In this case, if both errors are fast, or both slow, we subtract the less from the greater; but if one is fast and the other slow, add them together. Reduce the result to seconds by multiplying the minutes by 60 and adding in the seconds; divide this result by the number of days between the two given dates, and we have the chronometer's daily rate. *Now, is it gaining or losing?*

When both errors are fast.

If the first is less than the second, gaining.

If the first is greater than the second, losing.

When both errors are slow—

If the first is less than the second, losing.

If the first is greater than the second, gaining.

When one error is fast and the other slow—

If the first is fast and the second slow, losing.

If the first is slow and the second fast, gaining.

34. *Declination for Greenwich Time.* Look up the declination for the day on page 2 of the month in the Nautical

Almanac, and correct it for the hours and minutes by the "variation in 1 hour (18).

35. *Polar Distance.*—Subtract the corrected declination from 90° if the declination and latitude are the same name; but add 90° to the corrected declination if declination and latitude are different names. The result will be the polar distance.

Note.—When the latitude is 0°, the declination may either be added to or subtracted from 90° for the polar distance. When the declination is 0° the polar distance is 90°.

36. *Equation of Time for the Greenwich Time.* Take it out from page 2 of the month, Nautical Almanac, for the Greenwich day; and the variation in 1 hour. Multiply this hourly variation by the hours and tenth of an hour in the Greenwich time; point off from the right all decimals; and the result to the left is the correction for the equation of time in seconds; add if increasing; subtract if decreasing. Always note the rule for applying the equation of time, given at the head of the column, and place the sign + or — beside your work.

37. *The True Altitude.* To the observed altitude apply index error, if any, add if +, subtract if —; dip for height of eye from Table 14 Bowditch, or 5 Norie; always subtract; sun's correction (refraction and parallax), Table 18 Norie, or corresponding table in Bowditch, always subtract; sun's semidiameter from page 2 of the month, Nautical Almanac, for the date of the example, lower limb add, upper limb subtract. The result is the true altitude.

Note.—Table 9 Norie gives one correction for a lower limb observation which includes dip, refraction, parallax and semidiameter.

38. *The Hour Angle.* Add together the true altitude, latitude and polar distance; divide the sum by 2 for the half sum. From the half sum subtract the true altitude, and name the result remainder. Take out from Table 44 Bowditch, or 25 Norie, the logs, secant of the latitude, co-secant of the polar distance, co-sine of the half sum and sine of the remainder. Add these four logs together, rejecting all tens in the indices, and the sum will be the log of the hour angle found in Table 31

Norie. When using Bowditch, reject tens in the indices of secant and co-secant; add up the four logs and divide the sum by 2. The result is the log sine of the hour angle found in Table 44 Bowditch.

Note.—When the polar distance is greater than 90°, take out the secant of the corrected declination instead of the co-secant of the polar distance.

39. *Apparent Time at Ship.* Right below the hour angle place the date as given at the head of the example, the ship date, and 0 h 0 m 0 s; and if P. M. add; but if A. M. subtract the hour angle from the ship date by borrowing 24 hours, and make the date one day less. This will be the apparent time at ship.

40. *Mean Time at Ship.* To the apparent time at ship apply the corrected equation of time as directed in the Nautical Almanac. We then have the mean time at ship.

41. *The Longitude.* Place the mean time Greenwich under the mean time at ship and take their difference. The result is the longitude in time, which, converted into longitude, is the longitude of the ship. Tables 7 Bowditch, or 19 Norie may be used for this purpose; or multiply by 60 and divide by 4; or we may multiply by 3 and then by 5, which is easier.

42. *Name the Longitude.* If mean time Greenwich is greater than mean time at ship, name the longitude west. But if the Greenwich time is less than the ship time, name the longitude east.

Greenwich time best, longitude west.

Greenwich time least, longitude east.

Notes.—When latitude and corrected declination are both nothing, the true altitude subtracted from 90° 0′ 0″ and reduced to time by multiplying by 4 and dividing by 60, will be the hour angle. In some examples, the latitude at noon is given; it will then be necessary to reduce that latitude to the time of sights, by the course and distance run in the interval, in order to have the proper latitude to work for the longitude. Then you may carry ship's position on to noon.

EXAMPLE 1.

1902, February 8th, A. M. at ship; Lat. 48° 8′ N.; observed altitude sun's lower limb 10° 37′ 00″; eye 28 feet; chronometer time, February 8 d 5 h 17 m 6 s, which was fast up to date 1 m 31 s on mean time Greenwich; index error —30″. Find the longitude.

	d.	h.	m.	s.
Chron. Feb.	8	5	17	6
Err. Fast, —			1	31
M. T. G.	8	5	15	35

	Alt.
	10° 37′ 00″
I. E.	— 30
	10. 36. 30
Corr. T. 9 Norie +	6. 6
True Alt.	10. 42. 36

	Decl. S. Decr.	H'rly Var.
	15° 11′ 17″	47″.1
Corr. —	4. 10	5 .3
Corr. Decl.	15. 7. 7	1413
	90. 0. 0	2355
P. Dist.	105. 7. 7	6,0) 24,9.63
		4′ 10″

Alt..................	10° 42′ 36″	
Lat..................	48 . 8 . 0	. 0.175614
P. D..................	105 . 7 . 7	. 0.015294
Sum.......... 2)	163 .57 .43	
Half Sum..	81 .58 .51	. 9.144453
Remainder......	71 .16 .15	. 9 976361
		. 9.311722 =

	Equ. Time Incr.	H. Var.
	14 m 22 s	s.12
Corr.	+ 1	5.3
Corr. E. T.	14 23	36
		60
+ To App. Time.		.635

	Hour Angle.
	3 h 35 m 22 s
	8 d . 0 .00 .00
A. T. S............	7 .20 .24 .38
Equ. Time +	.14 .23
M. T. S..........	7 .20 .39 .01
M. T. G............	8 . 5 .15 .35
	8 h 36 m 34 s = } Table 19 Norie 129° 08′ 30″ W.
	3
	25 .49 .42
	5
Long.	129° 08′ 30″ W

Here, no daily rate is given for the chronometer, but the error is given up to date. One correction has been used for the altitude from Table 9 Norie. The secant of the corrected declination has been taken out because the polar distance is more than 90°. The logs are taken out for nearest one-half minute of arc only. Table 31 Norie has been used for the hour angle.

EXAMPLE 2.

1902, March 9th, P. M. at ship. Lat. 44° 43′ S.; observed altitude sun's lower limb 32° 10′ 40″; height of eye 18 feet; time by chronometer March 9 d 5 h 58 m 28 s, which was *fast* on mean noon at Greenwich on January 21st 8 m 12 s, and *gaining* daily 2 s; index error −1′ 25″. Required the longitude.

Chron. Mar	9 d	5 h	58 m	28 s
Err. Fast ...... —			8	.12
	9	5	.50	.16
Acc. Rate Gain —			. 1	.34
M. T. G........	9	5	.48	.42

Days in Jan......	10
" Feb......	28
" Mar	9
	47
	.2
	47.2
	2
	60) 94.4
Acc. Rate...	1 m 34 s

For Tenths of a Day.
5 h 50 m = 5 h .8

24) 58
2 Tenths of a Day.

Decl. Mar. 9	4° 44' 41'' S. decr.		
Corr.	— 5 .39		
Corr. Decl.	4 .39 .02		
	90 .00 .00		
Polar Dist.	85 .20 .58		

Var. in 1 hour.
58'' .5
5 .8
4680
2925
6,0) 33,9.30
Corr. 5' .39''

Equ. of Time Decr.

	10m	.53s	.0
Corr.	—	3	.6
	10	.49	.4
	+ to app. time		

H. Var.
0s.62
5 .8
496
310
Corr. 3s.596

Obs. Alt.	32°	10'	40''
I. E.	—	.1	.25
	32	.9	.15
Dip 18 ft.	—	4	.9
	32	.5	.6
Corr. Tab. .18	—	1	.24
	32	.3	.42
Semidia.	+	16	.7
True Alt.	32°	19'	49

Alt.	32°	19'	49''	
Lat.	44	.43	.00	. 0 . 148378
P. D.	85	.20	.58	. 0 . 001432
2)	162	.23	.47	95
H. Sum	81	.11	.53	. 9 . 184651
Rem.	48	.52	.04	. 9 . 876899
				7
				9 . 211462 =

Hour Angle

		h.	m.	s.
		3	10	19
	9d	0	0	0
A. T. S.	9	3	10	19
Equ. Time	+		10	.49
M. T. S.	9	.3	.21	.8
M. T. G.	9	.5	.48	.42
		h.	m.	s.
Longitude 36° 53' 30'' West =		2	27	34

The above is worked out to seconds of arc for example only, but the nearest half-minute is considered sufficiently accurate.

EXAMPLE 3.

1902, March 31st, A. M. at ship; Lat. 11° 2′ S.; ob-

served altitude sun's lower limb 33° 59′ 10″; eye 26 feet; time by chronometer 30 d 16 h 10 m 10 s, which was fast on mean time Greenwich 11 m 27 s on March 1st, and gaining daily 4.7 s; index error +2′ 53″. Required the longitude.

	d. h. m. s.
Chron. Mar.	30 16 10 10
Err. fast	— 11 .27
	30 15.58.43
Accd. rate, gain	— 2 .21
M. T. G.	30d 15.56.22
	24
Time from Noon 31d	8.03.38

	Decl. N. Incr.
Mar. 31st	3° 54′ 7″—
Corr. —	7 .51
Corr. decl.	3 .46 .16 N.
	90 00 00
P. D.	93 .46 .16

H. Var.
58″ .2
8 .1
582
4656
6,0) 47,1 .42
7′ 51″

Equ. Time decr.	
	4 m 28 s
Corr.	+ 6
Corr. E. T.	4m 34s
+ to app time	

H. Var.
s .76
8 . 1
76
608
6s .156

Obsd. Alt.	33° 59′ 10″
I. E. +	2 53
	34 .02 .03
Corr. Tab. 9 Norie	+ . 9 .42
True Alt	34 .11 .45

Daily gain	4s .7
Days elapsed	30
	6,0) 14,1 .0
Accd. rate	2m 21s

Alt.......	34° 11′ 45″		
Lat......	11 .02 .00	. 0 . 008103	Sec.
P. D.....	93 .46 .16	. 0 . 000939	Sec. of corr. decl.
	2) 139 .00 .01		
	69 .30 .00	. 9 . 544325	Cosine
	35 .18 .15	. 9 . 761821	Sine
Hour Angle....	3h 36m 18s	. 9 . 315188	
	31d .0 .0 .0		
A. T. S........	30d .20 .23 .42		
Equ. Time.....	+ 4 34		
M. T. S.......	30d .20 .28 .16		
M. T. G.......	30d .15 .56 .22		
Long. in Time.	4h 31m54s=		

Bowditch Tab. 7 / Norie Tab. 19 — Long. 67° 58′ 30″ E.

In this example the declination and equation of time are taken out for March 31st, the nearest noon, and worked backwards 8.1 hours to the Greenwich time.

The secant of the corrected declination is used, because the polar distance exceeds 90°. The logs are taken out to nearest one-half minute of arc from 25 Norie, useful for that purpose.

EXAMPLE 4.

1902, October 4th, A. M. at ship; observed altitude sun's

upper limb 53° 45′ 30″; height of eye 26 feet; time by chronometer October 4 d 6 h 49 m 07 s, which was *slow* on mean noon at Greenwich 12 m 48 s on June 30th; and *slow* on mean noon at Greenwich 9 m 30 s on August 24th; index error + 1′ 16″; latitude at noon 17° 21′ N.; run between sights and noon S. E. true 17 miles. Required the longitude at *noon*.

Green. Time.	Decl. S. Incr.	H, Var.	Equ. Time Incr.	H. Var.
Oct....4th 6h 49m 07s	Oct.. 4th 4° 05' 09''	58''	11m 01s —	0s.77
+ 9 30	+ 6 .40	6.9	+ 5	6 .9
4 6 58 37	4 .11 .49 S.	522	11m 06s	693
— 2 29	90 .00 .00	348	—From	462
M.T.G.4th 6h 56m 08s	P. D. 94 .11 .49	6,0)40,0.2	Ap.Time.	5.313
		6' 40''		

Minor Corrections.		
12m 48s slow.	July 31 days.	24) 6.9 hours.
9 .30 slow.	Aug. 24 "	.3 of a day.
3 .18	55 days.	41.3 days.
60		Rate...... 3.6 seconds.
55) 198 (3 s.6 daily gain.	Aug. 7 days.	2478
165	Sept. 30 "	1239
330	Oct. 4 "	6,0) 14,8.68
	41 days.	Accd. Rate 2m 29s

Obs. Alt. Sun's Upp. Limb.	
	53° 45' 30''
I. E........... +	1 .16
	53 .46 .46
Dip. 26 Ft...... —	5 .00
	53 .41 .46
Sun's Corr ..... —	0 .36
	53 .41 .10
Sem. dia. U. L.. —	16 .01
True Alt..........	53° 25' 09''

Run S. E. True, 17 Miles = D. Lat. 12'; Dep. 12'.

Lat. Noon......	17° 21'	N.
Diff. Lat.......	.12	N.
Lat. Sights......	17 .33	N.

Alt.........	53° 25'	
Lat	17 .33	. 0 . 020700
P. D	94 .12	. 0 . 001168
	2) 165 .10	
	82 .35	. 9 . 110873
	29 .10	. 9 . 687843
H. Angle	1h 59m 14s	. 8 . 820584
A. M	4d 0 0 0	
A. T. S	3d 22h 00m 46s	
Equ. Time..............	— 11 . 6	
M. T. S.................	3d 21 .49 .40	
M. T. G.................	4 6 .56 .08	
Long. in Time	9 . 6 .28s	
	3	
	27 .19 .24	
	5	
Long at Sights	136 .37 .00	West.
Dep. 12' = Diff. Long. =	— 13 .00	E.
Long. at Noon	136° 24' 00''	West.

The run S. E. is reversed mentally when allowing the difference latitude to find the latitude at sights. The hour angle

is subtracted from noon of the 4th because it is an A. M. sight.

EXAMPLES FOR PRACTICE.

1. 1902, December 17th P. M. at ship; in Manila Bay, in Lat. 14° 34′ 30″ N.; observed altitude sun's lower limb 27° 04′ 10″; height of eye 28 feet; time by chronometer 16 d 19 h 18 m 39 s, which was fast up to date 1 m 54 s; index error − 0′ 20″. Required the longitude for a check on the chronometer.

2. 1902, June 4th A. M. at ship; latitude 52° 10′ 30″ N.; observed altitude sun's lower limb 41° 05′ 30″; eye 28 feet; time by chronometer 4 days, 7 h 2 m 9 s, which was slow 37 m 12 s on May 1st, and losing 1.7 s daily; index error − 2′ 41″. Required the longitude.

3. 1902, December 10th, P. M. at ship; Lat. 29° 40′ 30″ N.; observed altitude sun's lower limb 12° 32′; eye 26 feet; time by chronometer 9 days, 19 h 4 m 4 s, which was 2 m 1 s fast up to date; index error + 30″. Required the longitude at sights and at noon. Run from noon till sights 35 miles S. 40° W. true.

4. 1902, May 11th, A. M. at ship; Lat. 39° 59′ S.; observed altitude sun's upper limb 11° 2′ 6″; eye 24 feet; time by chronometer, May 11 d 7 h 3 m 41 s, which was fast 2 m 4 s on mean time Greenwich on February 2nd, and was slow 1 m 17 s on mean time Greenwich on March 29th; index error − 3′ 05″. Required the longitude.

Answers at the end of the Guide.

TIME PROBLEMS.

43.—To Convert Longitude Into Time.—Multiply the longitude by 4 and divide by 60. The result will be its time equivalent.

EXAMPLE 1.

Turn 21° 44′ 31″ into time.

4

6,0)8,6.58.04

Ans. 1h 26m 58s.07

EXAMPLE 2.

Convert 175° 13′ 47″ into time

4

6,0)70,0.55.08

Ans. 11h 40m 55s. 13

44.—To Convert Time Into Longitude.—Multply the time by 60 and divide by 4. The result is its longitude value.

EXAMPLE 3.

Turn 6h 14m 12s into arc.

$$\begin{array}{rrl} & 60 & 120 \\ \hline 4\,) & 374 & 132 \\ \hline & 93^\circ & 33'\ 00'' \\ \hline\hline \end{array}$$

Or thus

$$\begin{array}{r} 6\text{h}\ 14\text{m}\ 12\text{s} \\ 5 \\ \hline 31\,.\,11\,.\,00 \\ 3 \\ \hline 93^\circ\ 33'\ 00'' \\ \hline\hline \end{array}$$

The second method in the above example seems easier, and is equal to multiplying by 15, which is the same as multiplying by 60 and dividing by 4, as shown in the first method.

Note.—Tables 7 Bowditch and 19 Norie; also tables A and B Norie, are useful in facilitating the above problems.

45.—To Convert Minutes and Seconds Into the Decimal of an Hour.—

First reduce the seconds to the decimal part of a minute by dividing them by 60, then divide the minutes and decimal of a minute by 60. The result is the decimal part of an hour.

EXAMPLE 4

Reduce 3h 40m 36s to hours and decimal part of hour. Thus:

60|36 Seconds.
60|40.6 Minutes and decimal part of minute.
| 3.68 Hours and decimal of hour nearly.

46.—To Convert the Decimal of an Hour Into Minutes and Seconds.

Multiply the decimal part in succession by 60, as follows:

EXAMPLE 5

Reduce 3h.68 to hours, minutes, and seconds.

$$\begin{array}{rl} 3\text{h}.68 & \\ 60 & \\ \hline 40.80 & \text{Minutes} \\ 60 & \\ \hline 48.00 & \text{Seconds} \end{array}$$

Therefore, 3.68 hours=3 hours, 40 minutes, 48 seconds, nearly.

Note.—It is usual for all practical purposes, simply to divide the minutes by 6 to obtain the decimal of an hour. If the seconds reach 30 or more, make the minutes one more.

[2] EXAMPLE 4

Reduce 3h 40m 36s to hours and 10ths of an hour. Thus:

6|41
|3.7=3 hours and 7 tenths nearly.

Here the seconds exceed 30, so we increase the minutes by one.

47.—TO REDUCE HOURS TO THE DECIMAL OF A DAY.—Annex a cipher to the hours and divide by 24.

[2] EXAMPLE 5

Reduce 10d 4h 56m to days and decimal of a day. Thus:

```
24 ) 50 (21      Therefore, 10d 4h 56m=10.21 days.
     48
     ——
     20     Note.—4h 56m are roughly taken as 5 hours.
```

Note.—The decimal part of a day is required approximately only, when figuring out the accumulated rate of a chronometer. One place of figures is considered sufficiently near; so that 10.2 days is the approx. answers to the last example.

COMPASS ERROR BY AZIMUTH.

The time given in the example may be mean time at ship, or apparent time at ship; but whatever time is given, we must reduce it to mean time at Greenwich, so as to correct the declination and equation of time for the Greenwich date. Mean time at Greenwich is sometimes given.

Mean Time at Ship Given.—If P. M., write the time down as given, with the date at the head of the question. But if A. M., add 12 to the hours and make the date one day less.

For the Mean Time at Greenwich. Under the mean time at ship as now written place the longitude in time, and add if west, subtract if east. The result is mean time at Greenwich. The longitude is turned into time by multiplying by 4 and dividing by 60 (43), or by use of Tables 7 Bowditch or 19 Norie.

Note.—If longitude west added exceeds 24 hours, subtract 24 hours and call the date one day more. If longitude east to be subtracted is greater than the hours, minutes and seconds of the mean time at ship, borrow 24 hours and call the date one day less.

Declination for the Greenwich Date. Take out the declination for the Greenwich date from page 2, Nautical Almanac, and its variation in 1 hour; multiply the variation in

1 hour by the hours and tenths of an hour of the Greenwich time, and score off the decimals from the right. What remains will be the correction for the declination; add, if increasing; subtract, if decreasing.

Polar Distance. When latitude and corrected declination are the same name, subtract the corrected declination from 90° 0′ 0″; but if different names, add 90° to the corrected declination. The result in either case is the polar distance.

Note. If the Latitude Is Nothing. When wanting to find the polar distance or name the true azimuth, suppose the latitude to have the opposite name to that of the corrected declination.

Equation of Time for Mean Time Greenwich. Take out the equation of time for the Greenwich day from page 2, Nautical Almanac, and its variation in 1 hour, multiply the variation in 1 hour by the hours and tenths of an hour; score off all decimals from the right of the product. What is left is the correction (in seconds) for the equation of time; to be added if the equation of time is increasing, and subtracted if decreasing.

The True Altitude is found by applying to the observed altitude index error +, add; –, subtract: dip, for height of eye, always subtract; sun's correction, subtract, and sun's semi-diameter from Nautical Almanac for the date, add for a lower limb; subtract for an upper limb. The altitude is corrected same as in meridian altitude (19) and chronometer questions (37). Table 9 Norie may be used for a lower limb *only;* it gives *one* correction.

Now Find the True Azimuth. Add together the polar distance, latitude and true altitude; divide the sum by 2; and take the difference between the half sum and the polar distance for the remainder. Then take out from Tables 44 Bowditch, or 25 Norie, secant of the latitude, secant of the altitude, co-sine of half sum, and co-sine of remainder. Subtract tens from index of secants; add these four logs; divide the sum by 2. Find this log as near as you can in the sine column of the same table, and the degrees and minutes corresponding will be half

the true azimuth, which multiplied by 2 will give the true azimuth.

48. *To Name the True Azimuth.* Reckon from south in north latitude and from north in south latitude; towards east if A. M., towards west if P. M.

Note.—If the latitude is nothing, name the true azimuth from the opposite pole from which the polar distance has been reckoned.

49. *Find the Compass Error.* If the compass azimuth given in the example is the *same* north or south, as the true azimuth, place the compass azimuth below the true. But if one is north and the other south, then first subtract the true azimuth from 180°, and name the remainder true azimuth north or south, same as the compass azimuth, and place the compass azimuth under it. Now, if the true and the compass azimuths are both east or both west, subtract the less from the greater, but if one is east and the other west, add them together. The result is the compass error.

Name the Error. Looking from the center of the compass towards the margin: if the true azimuth is to the *right* of the compass azimuth, the error is east; but if the true azimuth is to the *left* of the compass azimuth, the error is west.

Find the Deviation. Bring down the variation given in the example, under the error. If one is east and the other west, add them together; but if they are the same name, subtract the less from the greater. The result is the deviation.

To Name the Deviation. When the error and variation have the same name, mark the deviation the same as the error if the error is greatest; but contrary to the error if the error is less than the variation. When the error and variation have contrary names, mark the deviation same as the error. Or, using the compass card, mark off the error and variation at the north point of the compass, to the right of north if east, but to the left of north if west. Now, if the error is to the right of the variation, the deviation is *east,* but if the error is to the left of the variation, the deviation is *west.*

Note.—If the variation is 0°, the deviation is the same

as the error, and the same name. When the error is 0°, the deviation is the same as the variation, but of a different name. When latitude and declination are both nothing, the true azimuth is 90°, east if A. M.; west if P. M. If the compass azimuth is given due east, call it N. 90° E., or S. 90° E.; and if given due west, call it N. 90° W., or S. 90° W., reckoning from north, or south, like the true azimuth.

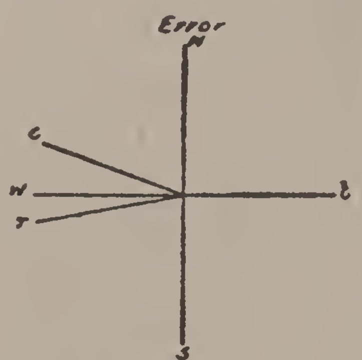
Greenwich Time Given. If any error on mean time is given, add if slow; subtract if fast.

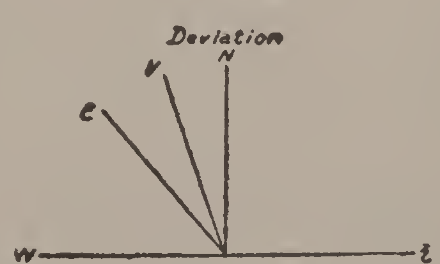
EXAMPLE 1.

1902, January 10th, P. M. at ship, at 4 h 29 m 28 s mean time at ship; Lat. 32° 47′ S.; Long. 28° 4′ W.; sun's bearing by compass W.×N.½N.; observed altitude sun's lower limb 34° 12′ 17″; height of eye 22 feet; variation 5° 29′ W. Required sun's true azimuth, error of compass and deviation.

M. T. S.	10d 4h 29m 28s	Long... 28° 4′ W		Decl. S. Decr.		Hourly Var.
Long. in Time	+ 1 .52 .16	4		22° 3′ 14″		21″.8
M. T. Green.	10d .6h .21m.44s	6,0) 11,2 .16		— 2 .20		6.4
		1h.52m .16s		22 .0 .54s		872
				90 .0 .0		1308
			Polar Dist...	67 .59 .06		6,0) 13,9 .52
						2′ 20″

Obsd. Alt. L.L.	34°12′17″				
Dip	— 4 .36				
	34 .7 .41	P. D.	67°59′ 6″		
Sun's Corr.	— .1 .17	Lat...	32 .47 .0	Sec.	.0.075346
	34 .6 .24	Alt...	34 .22 .41	Sec.	.0.083357
Sem. dia.	+ .16 .17		2) 135.8.47		
True Alt.	34° 22′ 41″		67.34.23	Cosine	.9.581465
			0.24.43	Cosine	.9.999989
					2) 19.740157
Half T. Azim.	47° 51′½			Sine...	.9.870078
	2				
True Azim.	N. 95 .43 W				
Comp. Azim.	N. 73 .7½ W				
Error	22 .35½ W				
Var.	5 .29 W				
Deviation	17° .6′½ W				



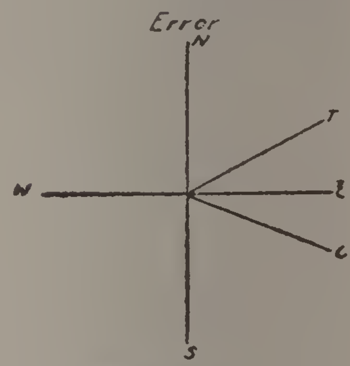


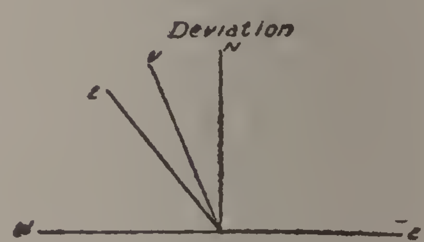
EXAMPLE 2.

1902, April 3rd, A. M. at ship, 8 h 59 m 47 s mean time ship; Lat. 31° 59′ S.; Long 67° 50′ E.; sun's compass azimuth E. ¼ S.; observed altitude sun's lower limb 35° 1′ 3″; eye 24 feet. Required the true azimuth and error of the compass; and supposing the variation 15° 45′ W., find the deviation.

M. T. S..............	2d 20h 59m 47s	Long.. 67° 50′ E	Decl. N. Incr.	H. Var.
Long. in Time...	— 4 .31 .20	4	4° 40′ 28″	57″.8
M. T. G............	2d 16 .28 .27	6,0) 27,1. 20	15 .54	16 .5
		4h 31m 20s	Decl... 4 .56 .22 N	2890
			90 .0 .0	3468
Obs. Alt..................	35° 1′ 3″		P. D..... 94°56′ 22″	578
Corr. Tab. 9 Norie...	+ 9 54			6,0) 95,3.70
True Alt........	35° 10′ 57″			15′ 54′

P. D......	94° 56′½		
Lat...............	31 .59	Sec......	.0.071501
Alt...............	35 .11	Sec......	.0.087612
	2) 162 .6½		
	81 .3	Cosine	.9.191933
	13 .53½	Cosine	.9 987108
			2) 19 338154
Half T. Azim......	27° 49′½ = Sine =		9.669077
	2		
T. Azim.......... N	55 .39 E		
	180 .0		
True Azim....... S	124 .21 E		
Comp. Azim.... S	87 .11 E		
Error......	37° 10 W		
Var.........	15 .45 W		
Deviation..........	21°.25′ W		



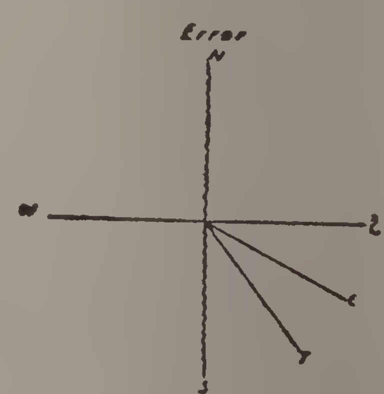


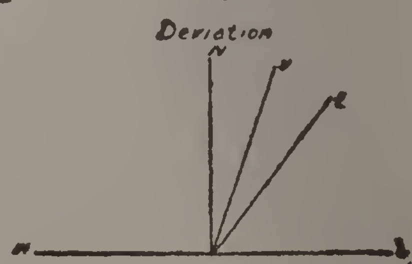
EXAMPLE 3.

1902, October 4th, A. M., 9 h 32 m 20 s mean time ship; Lat. 33° 36′ N.; Long. 133° 36′ W.; sun's compass azimuth E. × S.; observed altitude sun's *upper* limb 40° 20′ 30″; eye 26 feet; index error + 2′ 34″; variation 14° E. Required the true azimuth, compass error and deviation.

M. T. S.......	3d 21h 32m 20s	Long. 133° 36′ W.	Decl. S. incr.	H. Var.
Long. in Time.	+ 8 54 24	4	4° 5′ 9″	58″
M. T. G......	4d 6h 26m 44s	6,0)53,4 24	6 11	6.4
		8h 54m 24s	4 11 20 S	232
			90 0 0	348
			P.D... 94°11′20″	6,0)37,1.2
				6′11″

Obs. Alt............	40°20′30″			
I. E....................	+ 2.34			
	40 .23 .4	P. D...........	94° 11′	
Dip.....	— 5 .0	Lat............	33 .36	.0.079396
	40 .18 .4	Alt.............	40 .1	.0.115852
Sun's corr..........	— 1 .0		2) 167.48	
	40 .17 .4		83.54	.9.026386
Sem.dia. U.L......	— 16 .1		10.17	.9.992967
True Alt...........	40° 1′ 3″			2)19.214601
		H. T. Azim...	23°53′	.9.607300
			2	
		T. Azim....	S 47 .46 E	
		C. Azim....	S 78 .45 E	
		Error	30° 59′ E	
		Var..............	14 .0 E	
		Deviation.....	16° 59′ E	





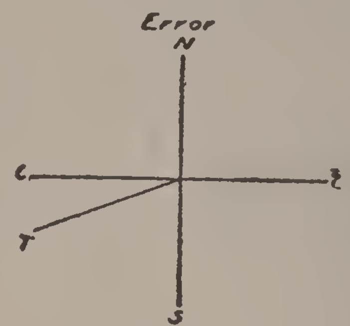
EXAMPLE 4.

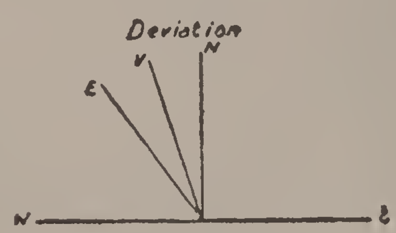
1902, September 23rd, P. M. at ship; Lat. 34° 23′ N.; Long. 23° 24′ E.; sun's compass azimuth west; observed altitude sun's lower limb 31° 49′ 10″; eye 22 feet; time by chronometer, correct for mean time Greenwich, September 23 d, 1 h 41 m 21 s. Required the true azimuth and error of compass; and the variation being 10° W., find the deviation.

```
                   d  h  m  s        Decl. N. Decr     H. Var.
M. T. G......Sept. 23  1 41 21          0° 11' 44"      58" .4       Obs. Alt......... 31° 49' 10" +
                                        —   1  39        1  .7     Corr. Tab. 9 Norie         9 .48
P. D......   89° 50'             Decl.  0° 10'  5"      4088          True Alt..... 31° 58' 58"

Lat........  34 .23  .0.08340          90   0   0       584
Alt........  31 .59  .0.07150    P.D.  89° 49' 55"  6,0)9,9.28
          2)156 .12                                      1' 39"

             78  .6 .9 .31430
             11 .44 .9 ,99083
               2) 19 .46003
                  9 .73001=½ True Azim...... 32°29'
                                                   2
                          True Azim ......S 64 .58 W
                          Comp. Azim ...S 90 .00 W
                              Error........ 25 .02 W
                              Var.......... 10 .00 W
                          Deviation........ 15° 02' W
```





In the preceding examples the logs have been taken out, in some cases to the nearest half-minute, and in others to the nearest minute of arc only. The nearest minute may be considered sufficiently accurate in working an azimuth.

The following examples for practice have been worked to the nearest half-minute of arc, and the declinations corrected from the nearest noon. The altitudes are corrected by one correction from *Table 9 Norie,* except in the case of an upper limb observation, when dip, sun's correction and semi-diameter are applied separately. The student may use the tables he likes best, or is accustomed to. The result will be about the same.

EXAMPLES FOR PRACTICE.

1. 1902, March 15th, P. M. at ship, 2 h 19 m 00 s mean time ship; Lat. 33° 30′ S.; Long. 79° 10′ E.; sun's compass azimuth N. W. ¼ N.; altitude sun's lower limb 46° 2′ 45″;

eye 22 feet; variation 16° W. Required the true azimuth, compass error and deviation.

2. 1902, April 5th, A. M. 9 h 48 m 15 s mean time ship; Lat. 32° 32′ S.; Long. 82° 32′ W.; altitude sun's *upper* limb 40° 23′ 14″; eye 26 feet; compass azimuth N. E. × N.; variation 17° 11′ E. Find true azimuth, error of compass and deviation.

3. 1902, May 6th, P. M. 3 h 47 m 10 s mean time ship; Lat. 34 ° 5′ N.; Long. 122° 59′ W.; altitude sun's lower limb 37° 32′ 2″; eye 25 feet; compass bearing W. 3° 20′ N.; variation 14° 5′ E. Find true azimuth, compass error and deviation.

4. 1902, June 5th, A. M., 9 h 00 m 20 s mean time ship; Lat. 33° 1′ N.; Long. 137° 3′ E.; altitude sun's lower limb 50° 02′ 14″; compass azimuth E. ½ N.; eye 24 feet; variation 2° 4′ W. Required true azimuth, compass error and deviation.

Answers at the end of the Guide.

TIME AZIMUTH.

The Sun's True Bearing for every ten minutes between sunrise and sunset, is given in the azimuth tables, issued by U. S. Navy Department; also, for every 4 minutes, in Burdwood's and Davie's Azimuth Tables. In the following examples the American publication has been used.

These tables are to be entered with the latitude, the apparent time at ship, and the corrected declination. The latitude is found at the top of the page, and the apparent time at ship at the sides, A. M. on the left, P. M. on the right. The declination is also found at the top, under the latitude. Be careful when looking up the latitude to take it out according as the declination and latitude have the same, or different names, as the case may be.

Apparent time at ship must always be used to get the sun's true bearing from these tables. If mean time at ship is given in the example, it must be reduced to apparent time at ship by applying the equation of time, corrected by its variation

in 1 hour for the hours and tenths of an hour of the Greenwich date. The rule at the head of the equation of time column will guide you in applying it to mean time. The result will be apparent time ship.

If Greenwich mean time is given apply the longitude in time; east, add; west, subtract. The result is mean time ship, then apply the equation of time as above directed, and we have apparent time ship for the tables. When the time is given Greenwich mean time and the example begins with A. M. at ship, then this apparent time at ship will exceed 12 hours, and we must subtract 12 hours before entering the tables.

The declination should be taken out and corrected for the Greenwich time. Or, if taken out for ship's date, it should be corrected for longitude by Table 21 Norie.

Often at the examinations it is considered sufficiently accurate to enter the azimuth tables with the nearest degree of latitude and declination, and the nearest minute of time; though finer results can be reached, if the candidate is fond of unnecessary figures.

Owing to continual change of longitude at sea, the clock or watch is usually *away off* for apparent time at ship; then compare the timepiece with the chronometer, noting the time by both, say to the nearest half-minute. Allow the error on the chronometer to date, work up the longitude by D. R., turn it into time and apply to Greenwich time: east, add; west, subtract. This is now mean time ship. Apply the equation of time, and we have apparent time ship. The difference between this and the time noted by the clock or watch is its error. It should be corrected for convenience.

EXAMPLE 1.

Find the true azimuth for latitude 48° N., at 5 h 40 m P. M. apparent time ship; declination 16° N. Answer N. 82° 43′ W.

EXAMPLE 2.

1902, May 25th, Lat. 47° N.; Long. 59° W., at 3 h 50 m P. M. apparent time ship; sun's compass bearing N. 56° 15′

W.; variation 31° W. Required the deviation by azimuth tables.

True Azim............	N 98° 50′ W
Comp. Azim...........	N 56° 15′ W
Error.................	42 35 W
Var.	31 .00 W
Deviation.............	11° 35′ W

Note the rules at the foot of the azimuth tables for naming the true azimuth. These tables are self-explanatory.

EXAMPLE 3.

1902, February 2nd, Lat. 40° N.; Long. 48° W., 9 h 50 m A. M., apparent time ship; sun's compass bearing N. 139° 20′ E.; variation 7° 19′ W. Find the deviation.

Per. Azim. Tables, Sun's True Bearing......	N 145° 19′ E
Comp. Bearing............	N 139 20 E
Error..........	5 59 E
Var...........	7 19 W
Deviation......	13° 18′ E

The azimuth tables may also be used to obtain the true bearing of the moon, stars or planets, provided the object's declination is within the limits of the tables. In such cases, the hour angle is used instead of the apparent time ship.

Rule for the Hour Angle. To the astronomical apparent time (that is, reckoning from the previous noon) add the apparent sun's right ascension. The sum is the right ascension of the meridian. Now, subtract the body's right ascension, and we have the hour angle needed, to be sought for in the P. M. column of the azimuth tables.

EXAMPLE 4.

1902, May 27th, Lat. 51° N., 11 h 42 m P. M., apparent time ship; star Spica bear by compass N. 93° W.; local variation 35½° W. Required the deviation.

A. T. S..........	11h 42m
Sun's App. R. A.....	4 .13
R. A. of Mer........	15 55
Star's R. A..........	13 20
Star's Hour Angle...	2 35

Enter the azimuth tables with Lat. 51° N. stars declina-

tion 10° 39′ S. (latitude and declination contrary names), and the hour angle 2 h 35 m, and take out from the P. M. column.

Star's True Bearing...............		N 139° 0′ W
Star's Comp. Bearing.............		N 93 0 W
	Error...........	46 0 W
	Var.............	35 30 W
	Deviation	10° 30′ W

EXAMPLES FOR PRACTICE.

1. Find time azimuth for Lat. 34° S., sun's declination 14° S.; apparent time at ship 3 h 10 m P. M.

2. What is the sun's true azimuth for Lat. 20° N., declination 13° S., and apparent time at ship 7 h 20 m A. M.

3. Required sun's true azimuth for Lat. 33° N., declination 12° S., and apparent time at ship 9 h 30 m A. M.

4 Find sun's true azimuth for Lat. 40° S., declination 10° N., and apparent time at ship 2 h 40 m P. M.

Answers at the end of the Guide.

LATITUDE BY REDUCTION TO THE MERIDIAN.

The exact time from noon, the latitude by account and the corrected declination are necessary in obtaining the latitude by this process. To the time by watch as given apply its error; + if slow; – if fast. Then apply the difference of longitude in time for the run of the ship since the error on apparent time was found; add if easting, subtract if westing. The result is apparent time at ship. Now, if it is a P. M. example, the apparent time at ship will be 0 hours, some minutes and seconds, and these minutes and seconds will be the *time from noon.* But if the example is A. M., the apparent time at ship will be 23 hours, some minutes and seconds, reckoning from the preceding noon, and this subtracted from 24 hours will be the *time from noon.*

We need the Greenwich time for which to take out and correct the sun's declination. To the apparent time at ship apply the longitude in time: + if west, – if east. The result is

apparent time Greenwich. Take out the declination for the Greenwich date and correct it in the usual manner for the hours and minutes of the Greenwich time. Correct the observed altitude, also in the usual way. Then take out from tables.

Time from Noon..............	Log. rising		29 Norie
Latitude	Cosine 44	Bowditch,	25 Norie
Declination	Cosine 44	"	25 Norie

Add these logs, rejecting 20 from the index, and take out the number corresponding to their sum from 42 Bowditch, or 24 Norie. To this add the natural sine of the true altitude, Table 26 Norie, *using five figures only.* Seek the sum in the same table. The degrees at the foot and minutes at the right hand side, *natural co-sine,* will be meridian zenith distance, to be named contrary to the sun's bearing.

Now Find the Latitude. Bring down the corrected declination, and if it and the zenith distance have like names, add them together; but if contrary names, subtract the less from the greater, and the result is the latitude, of the same name as the greater.

Mean Time at Greenwich Given. Take out the declination and equation of time from page 2, Nautical Almanac, and correct them for the Greenwich time as stated, by the variation in 1 hour. If chronometer time is given with an error on mean time, see that its error is applied, in order to correct the declination and equation of time for the correct mean time Greenwich. To this mean time Greenwich we must apply the longitude in time, east +, west –, and call the result mean time ship. To the mean time ship apply corrected equation of time by the rule at the head of the column in Nautical Almanac. We now have the apparent time ship, and this apparent time ship gives the *time from noon,* as prevoiously explained. Remember that the latitude by reduction to meridian is the latitude of ship at time of observation, so that to reduce the latitude to noon, we must allow the difference latitude on the course and distance made in the interval.

Ex-meridian tables are used in practice at sea, from which a correction for the observed altitude is taken out by inspection; and from the altitude *thus corrected,* the latitude at time of observation is found in the same manner as by meridian alti-

tude; but at the examinations the work is done by calculation, as shown in this chapter, or by a similar method.

EXAMPLE 1.

1902, January 7th, P. M. at ship; Lat. by account 27° 3′ N.; Long. 67° 15′ W.; observed altitude sun's lower limb south of observer 39° 57′ 00″; eye 23 feet; time by watch 7 days, 0 h 22 m 44 s, which was slow 6 m 52 s on apparent time ship; difference longitude made, east 21 miles, since error on apparent time ship was found; index error – 2′ 45″. Required the latitude by reduction to meridian.

	d h m s	Diff. long.		Decl. S. decr.	H. Var.
Time by Watch..	7 0 22 44	21' E		22° 27' 23"	18" .5
Err. slow....	+ 6 52	4	Corr.	— 1 32	5
	7 0 29 36	6,0)8,4	Corr. decl.	22° 25 51	6,0)9,2.5
Diff. long. E....	+ 1 24	1m 24s			1' 32"
A. T. S.....	7 0 31 0	Long. 67° 15' W			
Long. in T. W..	+4 29 0	4			
A. T. G....	7d 5h 0m 0s	6,0) 26,9 .0			
		4h 29m			

Obs. Alt.....	39° 57' 0" S.
I. E.. ...	— 2 45
	39 54 15
Dip.......	— 4 42
	39 49 33
Sun's Corr.	— 1 2
	39 48 31
Sem. dia....	+ 16 17
True Alt....	40 4 48

Time from Noon...	31m 0s	Log. ris.	2.96067
Latitude...............	27° 3'	Cosine	9.94969
Corr. decl..	22° 26'	Cosine	9.96582
Number.......	751.9	Log.	.2.87618
T. Alt. 40°5', nat. sine......	64390.1		
Nat. cosine...........	65142.0	=Mer. Z. dist.	49° 21' 05" N.
		Decl............	22 25 51 S.
		Latitude......	26° 55' 14" North

EXAMPLE 2.

1902, April 11th, A. M. at ship; Lat. account 23° 40′ S.; Long. 118° 20′ E.; altitude sun's lower limb 56° 51′ 57″ N. of observer; eye 22 feet; time by watch 10 days, 23 h 28 m 15 s, which was fast on apparent time ship 3 m 43 s; difference longitude 28 m W. since the error was found. Required the latitude by reduction to the meridian.

		D Long.	Long. 118° 20' E.	Decl. N. Incr.	H. Var.
Watch............	10d 23h 28m 15s	28' W	4	7° 42' 13"	55".6
Err. fast.........	— 3 43	4		+	
	10 23 24 32	6,0)11,2	6,0)47,3 20	Corr. 14 22	15 .5
Diff. long. W.	— 1 52	1m 52s	7h 53m 20s	7 56 35	2780
App. T. S......	10 23 22 40	A. T. S.	23h 22m 40s		2780
Long. in T. E	— 7 53 20		24 0 0		556
A. T. G.........	10 15 29 20	T. F. Noon	37m 20s		6,0)86,1.80
					14' 22"

Obs. Alt.........	56° 51' 57" N
Dip...............	— 4 36
	56 47 21
Sun's corr......	— 34
	56 46 47
Sem. dia.........	+ 15 58
True Alt.........	57° 2' 45"

Time F. N.......	37m 20s	Log. ris.	3 . 12184
Lat................	23° 40'	Cosine	9 . 96185
Decl...............	7° 57'	Cosine	9 . 99581
Number.........	1201	Log.	3 . 07950
T.Alt.57°3' Nat. sine	83915		
Nat. Cosine... —	85116	Mer. Z. Dist.	31° 40' S
		Decl.........	7 57 N
		Latitude..	23° 43' South

EXAMPLE 3.

1902, November 23rd, A. M. at ship; Lat. by accouut 11° 43′ N.; Long. 128° 50′ W.; observed altitude sun's lower limb south of observer 56° 29′ 35″; eye 19 feet; time by watch 23 days 0 h 56 m 10 s, which was fast on apparent time ship 1 h 34 m 18 s; difference of longitude made eastward 14′ after the error on apparent time ship had been found. Required the latitude at noon, ship having made 4′ south between noon and the time of observation.

Watch.....	23d	0h	56m	10s
Err........	—	1	34	18
	22d	23h	21m	52s
D. Long. E.		+		56
A. T. S....	22d	23h	22m	48
Long. in T.	+	8	35	20s
A. T. G....	23d	7h	58m	8s

D. Long.
14′
4
56s

Long. 128° 50′ W.
4
60) 51,5.20
8h 35m 20s

Decl. S. Incr.	20°	12′	51″
Corr	+	4	15
Corr. Dec.	20	17	6

H. Var.
31″.9
8
6,0) 25,5.2
4′ 15″

A. T. S.....	23h	22m	48s
	24	0	0
T. F. Noon.		37m	12s

Alt. L. L.........	56°	29′	35″ S.
Corr. Tab. 9 Norie	+	11	15
True Alt.........	56	40	50

T. F. Noon 37m 12s		Log. Ris.	3 . 11873
Lat. Acc .. 11° 43′		Cosine ..	9 . 99085
Corr. Decl. 20° 17′		Cosine ..	9 97220
Natural Number	1207	Log.....	3 . 08178
T. Alt. 56° 41′ Nat. Sine	83565		
Nat. Cosine............	84772	= M. Z. D.	32° 2′ N.
		Decl.	20 17 S.
		Lat. at sights	11° 45′ N.
		Diff. Lat.	4 S.
		Lat. at noon	11° 41′ N.

EXAMPLE 4.

1902, October 19th at ship; Lat. by account 35° 39′ N.; Long. 143° 37′ W.; altitude sun's *upper limb* 44° 9′ S.; eye 23 feet; time by chronometer October 19th 8 h 47 m 8 s; correct mean time Greenwich. Required the latitude at noon; ship ran N. W. × N. 12 knots per hour.

M.T.G.	19d	8h	47m	8s
Long. in T.	—	9	34	28
M.T.S.	18d	23h	12m	40s
Eq. Time	+		14	53
A.T.S.		23h	27m	33s
		24	0	0
T. F. Noon			32m	27s

Obs. Alt.	44°	9′		S.
Dip	—	4	42	
	44	4	18	
Corr.	—		53	
	44	3	25	
Sem. dia. U.L.	—	16	5	
True Alt.	43°	47′	20″	

Long. 143° 37′ W.
4
6,0) 57.4 28
9h 34m 28s

Equa. Time
14m 49s
corr. + 4
14m 53s
+ to M. Time.

Decl. S. incr. 9° 44′ 20″
+ 8 corr.
corr. decl. 9° 52′ 20″ S.

H. Var.
.47
8.8
376
376
4.136

H. Var.
54.5′
8.8
4360
4360
6,0) 47.9.60
7′ 59.6′

T. F. Noon	32m	27s	log ris.	3 . 00032
Lat. acc.	35°	39′	cosine	9 . 90987
Corr. decl.	9°	52′	cosine	9 . 99353
Nat. Number	801.2		Log.	2 . 90372

T. Alt. 43° 47′ 20″ Nat. sine 692003
Nat. Cosine 700015=M.Z.D. 45° 34′ 18″ N.
Decl. 9 52 20 S.
Lat. at Observation 35° 41′ 58″ N.
Diff. Lat. 5 24 N.
Lat. at Noon 35° 47′ 22″ North.

Course N 3 pts. W 6′ .5=d. lat. 5.4
6
24″

EXAMPLES FOR PRACTICE.

1. 1902, January 4th, P. M. at ship; Lat. by account 33° 36′ N.; Long. 159° 24′ W.; observed altitude sun's lower limb south of the observer 32° 57′ 45″; eye 15 feet; time by watch 4 days, 2 h 47 m 43 s, which was fast 2 h 23 m 30 s on apparent time at ship; difference longitude made eastward 33 miles since the error on apparent time was found. Required the latitude by reduction to the meridian.

2. 1902, July 16th, A. M. at ship; Lat. acount 25° 33′ S.; Long. 63° 25′ E.! observed altitude sun's lower limb 42° 39′ 25″ N.; height of eye 19 feet; time by watch 15 days, 23 h 55 m 19 s, which was fast 6 m 37 s on apparent time ship; difference longitude made west 39 miles since the error was determined. Required latitude by reduction to the meridian.

3. 1902, July 6th, A. M. at ship; Lat. account 38° 38′ S.; Long. 153° 37′ W.; altitude sun's lower limb 27° 58′ 35″ N.; eye 14 feet; time by watch 6 days, 0 h 39 m 24 s, which was fast 59 m 34 s on apparent time ship; difference longitude made westward 54′ after error on apparent time was found. Required the latitude by reduction to meridian.

4. 1902, August 9th at ship; Lat. account 29° 29′ S.; Long. 84° 37′ W.; observed altitude sun's lower limb 43° 41′ 40″ north of observer; eye 22 feet; time by chronometer August 9 d 6 h 4 m 30 s, which was slow 1 m 21 s on mean time at Greenwich. Required the latitude by reduction to meridian.

Answers at the end of the Guide.

LATITUDE BY MERIDIAN ALTITUDE OF A STAR.

If the sextant has an index error, apply it to the altitude as read + add, – subtract. Then correct for dip by Table 14 Bowditch, or Table 5 Norie; always subtract; and refraction, Table 20 Bowditch, or Table 18 Norie. The result will be the true altitude. No semi-diameter or parallax are needed. The true altitude is now taken from 90° 0′ 0″ and we have the zenith distance, which must be named contrary to the bearing of the star when observed, north or south. Now place the star's declination under the zenith distance and if they are both north or both south, add them together; but subtract the least from the greatest if they have contrary names. The result is the latitude, same name as the greater.

The declination of a star needs no correction, but is taken at sight from the Nautical Almanac. It sometimes happens that the star cannot be found in the Nautical Almanac by the name given in the example. If this is the case, Tables 48 Bowditch, or 14 Norie, giving different names for the same star, will be helpful. The other name thus found is the one to seek for in the Nautical Almanac when taking out the declination. Table 15 Norie gives *one* correction for a star's altitude; always subtract.

EXAMPLE 1.

1902, February 2nd; observed meridian altitude star Sirius was 43° 27′ 15″ bearing south; eye 24 feet; index error +0′ 45″. Required the latitude.

Obs. Alt.	43°	27′	15″	S
I. E.	+		45	
	43	28	.0	
Dip 24 ft.	—	4	48	
	43	23	12	
Ref. for Alt.	—	1	0	
	43	22	12	
	90	0	0	
Zen. dist	46	37	48	N
Star's decl.	16	34	53	S
Latitude	30°	2′	55	N

SHORT METHOD

O. Alt.	43°	27′ ¼	S
I. E.	+	¾	
	43	28	
Corr. T. 15 Norie	—	5¾	
	43	22¼	
	90	0	
	46	37¾	N
	16	35	S
Lat	30°	2′ ¾	N

EXAMPLE 2.

1902, April 7th; observed meridian altitude star Canopus was 49° 55′ 10″, bearing south; height of eye 20 feet; index error – 1′ 20″. Required the latitude.

Obs. Alt.	49°	55′	10″	S.
I. E.	—	1	20	
	49	53	50	
Dip.	—	4	23	
	49	49	27	
Ref.	—		48	
True A.	49	48	39	
	90	0	0	
Z. Dist.	40	11	21	N.
Stars D.	52	38	31	S.
Latitude	12°	27′	10″	South

Approx. Shorter Method

Obs. Alt.	49°	55′	S.
I. E.	—	1	
	49	54	
Tab. 15 Norie	—	5	
T. Alt.	49	49	
	90	0	
Z. D.	40	11	N
Decl.	52	38½	S.
Lat.	12°	27′½	South

EXAMPLES FOR PRACTICE.

1. 1902, March 29th; observed meridian altitude star Algenib 54° 0′ 12″, bearing south; eye 22 feet; index error – 1′ 15″. Required the latitude.

2. 1902, December 17th; observed meridian altitude star Antares 52° 47′ 0″, bearing north; eye 26 feet; no index error. Required the latitude.

3. 1902, October 15th; observed meridian altitude star Castor, bearing north, 64° 17′ 55″; eye 17 feet. Required the latitude.

4. 1902, July 24th; observed meridian altitude star Aldebaran, bearing south, was 56° 1′ 45″; eye 25 feet. Required the latitude.

This last altitude is corrected by Table 15 Norie.

Answers at the end of the Guide.

LATITUDE BY POLARIS.

Several tables are in use, giving corrections for the altitude of this useful little star, in order to get the latitude. Those in the Nautical Almanac are splendid, and others are good. The table given in this work is considered very useful and complete.

We need the sidereal time of observation (right ascension of the meridian).

If Apparent Time at Ship Is Given. To the apparent time at ship add the sun's right ascension, page 1, Nautical Almanac, and the result is the right ascension of the meridian.

If Mean Time at Ship Is Given. To the mean time at ship add the sidereal time (page 2, Nautical Almanac), taken out for the Greenwich date and accelerated for the hours, minutes and seconds of the Greenwich time. This gives us the sidereal time of observation.

Note.—The Greenwich time is sometimes given in the example; if not given, we must find it before we can accelerate the sidereal time, or correct the sun's right ascension. The longitude in time west, added to, east subtracted from the time at ship will give the time at Greenwich.

Correct the observed altitude for index error (if any), dip and refraction, to get the reduced altitude (true altitude). Table 15 Norie gives one correction for a star altitude, which includes dip and refraction. Now, enter the table given on page 62 with the right ascension of the meridian, under true altitude, and take out the correction, adding to or subtracting from the reduced altitude, as that part of the table directs. The result is the latitude.

EXAMPLE 1.

1902, January 28th, 6 h 47 m 14 s A. M. mean time at ship; Long. 166° 59′ E.; observed altitude of pole star 46° 54′ 20″; eye 30 feet. Required the latitude.

M. T. S......	27d	18h	47m	14s
Long. in Time...	—	11	7	56
M. T. G......	27d	7h	39m	18s

Long. E.
166° 59′
4
6,0)66,7 56
11h 7m 56s

Obs. Alt..........	46°	54′	20″
Dip...........	—	5	22
	46	48	58
Ref.........	—		54
True Alt...	46	48	4
Corr. from table...	1	5	+
Latitude...	47°	53′	4″ North

M. T. S.........	27d	18h	47m	14s
Sid. Time.....	27d =	20	23	19
Accel............	7h =		1	9
"	39m =			6
"	18s =			0
Sid. Time Obs.		15h	11m	48s

Note.—The above example being A. M., we add 12 to the hours and make the date one day less; this gives us *astronomi-*

cal mean time ship. Then we apply the longitude in time, east subtract, to get mean time Greenwich. The sidereal time is then accelerated for the hours, minutes and seconds of the Greenwich time, and added to the mean time ship to obtain sidereal time of observation.

EXAMPLE 2.

1902, March 21st, P. M. at ship; Long. 29° 59′ W.; chronometer, 21 days, 11 h 54 m 58 s mean time Greenwich; observed altitude of star Polar is 64° 59′ 50″; index error + 1′ 40″; eye 26 feet. Required the latitude.

M. T. G. Mar. 21d	11h	54m	58s	
Long. in Tine... —	1	59	56	
M. T. S........ 21	9	55	2	
Sid. Time... 21d =	23	52	16	
Accel ... 11h =		1	48	
" ..... 54m =			9	
Sid. Time Obs.	9h	49m	15s	

Long. W.
29° 59′
4
6,0) 11,9 56
1h 59m 56s

Obs. Alt...	64°	59′	50″
I. E..... +		1	40
	65	1	30
Table 15 Norie —		5	18
Red. Alt......	64	56	12
Corr........... +		44	0
Latitude.....	65°	40′	12″ N

Note.—When turning Greenwich time to ship's time, as in this last example, longitude in time east is added, and west subtracted.

EXAMPLE 3.

1902, January 30th, 6 h 39 m P. M., apparent time ship; Long. 179° 30′ W.; observed altitude Polaris 51° 51′ off the meridian; eye 28 feet. Required the latitude.

A. T. S. Jan.	30d	6h	39m
Long. in Time +		11	58
A. T. G........	30	18	37

Long. W.
179° 30′
4
6,0) 71,8 .0
11h 58m

Sun's R. A. Incr.	20h	48m	34s
Corr...... +		3	12
Red. R. A...	20	51	46
A. T. S......	6	39	0
Sid. Time Obs.	3h	30m	46s

H. Var.
10s .3
18 .6
618
824
103
6,0) 19,1 .58
3m 12s

Obs. Alt..........	51°	51′	0″
Dip........... —		5	11
	51	45	49
Ref............ —			44
Red. Alt.....	51	45	5
Corr....... —	1	1	0
Latitude.........	50°	44	5″ North.

EXAMPLES FOR PRACTICE.

1902, May 12th, 11 h 0 m 30 s P. M. mean time ship; Long. 113° 2′ W.; observed altitude pole star 41° 10′ 17″; eye 26 feet. Required the latitude.

1902, September 22nd, 2 h 10 m A. M. mean time ship; Long. 151° 59′ E.; observed altitude Polaris 29° 58′ 50″; index error + 3′ 10″; eye 28 feet. Find the latitude.

Answers at the end of the Guide.

CORRECTION FOR THE ALTITUDE OF STAR POLARIS, FOR THE YEARS 1902, 1903, 1904, 1905 and 1906.

RIGHT ASCENS'N OF MERIDIAN	SUBTRACT FROM TRUE ALTITUDE		RIGHT ASCENS'N OF MERIDIAN	ADD TO TRUE ALTITUDE		RIGHT ASCENS'N OF MERIDIAN	ADD TO TRUE ALTITUDE		RIGHT ASCENS'N OF MERIDIAN	SUBTRACT FROM TRUE ALTITUDE	
	50°	70°		50°	70°		50°	70°		50°	70°
0 h 0 m	1° 7'	1° 7'	7 h 20 m	0° 0'	0° 0'	12 h 0 m	1° 7'	1° 7'	19 h 30 m	0° 1'	0° 0'
0 30	1 10	1 10	7 30	0 2	0 4	12 30	1 10	1 10	19 40	0 4	0 3
1 0	1 12	1 12	7 40	0 6	0 7	13 0	1 12	1 12	19 50	0 7	0 6
1 30	1 12	1 12	7 50	0 9	0 10	13 30	1 12	1 12	20 0	0 10	0 9
2 0	1 11	1 11	8 0	0 12	0 13	14 0	1 11	1 11	20 10	0 13	0 12
2 20	1 10	1 10	8 10	0 15	0 16	14 30	1 10	1 10	20 20	0 16	0 15
2 40	1 8	1 8	8 20	0 18	0 19	14 40	1 8	1 9	20 30	0 19	0 18
3 0	1 6	1 6	8 30	0 21	0 22	15	1 6	1 6	20 40	0 22	0 21
3 10	1 4	1 4	8 40	0 24	0 25	15 10	1 5	1 5	20 50	0 25	0 24
3 20	1 3	1 3	8 50	0 27	0 28	15 20	1 4	1 4	21 0	0 28	0 27
3 30	1 1	1 1	9 0	0 30	0 31	15 30	1 2	1 2	21 10	0 31	0 30
3 40	1 0	0 59	9 10	0 33	0 34	15 40	1 0	1 0	21 20	0 34	0 33
3 50	0 58	0 57	9 20	0 35	0 36	15 50	0 59	0 59	21 30	0 37	0 36
4 0	0 56	0 55	9 30	0 38	0 39	16 0	0 57	0 57	21 40	0 39	0 39
4 10	0 54	0 53	9 40	0 41	0 41	16 10	0 55	0 55	21 50	0 42	0 41
4 20	0 52	0 51	9 50	0 43	0 44	16 20	0 53	0 53	22 0	0 45	0 44
4 30	0 49	0 49	10 0	0 46	0 46	16 30	0 51	0 51	22 10	0 47	0 46
4 40	0 47	0 46	10 10	0 48	0 49	16 40	0 49	0 49	22 20	0 49	0 49
4 50	0 44	0 44	10 20	0 50	0 51	16 50	0 46	0 46	22 30	0 52	0 51
5 0	0 42	0 41	10 30	0 52	0 53	17 0	0 44	0 44	22 40	0 54	0 53
5 10	0 39	0 39	10 40	0 55	0 55	17 10	0 41	0 41	22 50	0 56	0 55
5 20	0 37	0 36	10 50	0 57	0 57	17 20	0 38	0 39	23 0	0 58	0 57
5 30	0 34	0 33	11 0	0 59	0 59	17 30	0 35	0 36	23 20	1 1	1 1
5 40	0 31	0 30	11 20	1 2	1 2	17 40	0 33	0 34	23 40	1 4	1 4
5 50	0 28	0 27	11 40	1 5	1 5	17 50	0 30	0 31	24 0	1 7	1 7
6 0	0 25	0 24	12 0	1 7	1 7	18 0	0 27	0 28	....	....	....
6 10	0 22	0 21	....	....	....	18 10	0 24	0 25	....	....	....
6 20	0 19	0 18	....	....	....	18 20	0 21	0 22	....	....	....
6 30	0 16	0 15	....	....	....	18 30	0 18	0 19	....	....	....
6 40	0 13	0 12	....	....	....	18 40	0 15	0 16	....	....	....
6 50	0 10	0 9	....	....	....	18 50	0 12	0 13	....	....	....
7 0	0 7	0 6	....	....	....	19 0	0 9	0 10	....	....	....
7 10	0 4	0 3	....	....	....	19 10	0 6	0 7	....	....	....
....	....	....	....	....	....	19 20	0 2	0 4	....	....	....

LONGITUDE BY STAR.

The formal rules for working out longitude by *star* are, in many ways, so similar to those of the sun, that very little additional explanation is necessary. The longitude is simply the difference between the sidereal time at ship and the sidereal time at Greenwich. The pupil should be familiar with mean time and sidereal time.

EXAMPLE.

1902; suppose mean time Greenwich January 10th 7 h 12 m 14 s, and it be required to find the reduced sidereal time, or mean sun's right ascension. Take out from Nautical Almanac, right-hand column, for the Greenwich date, the sidereal time at mean noon, as under.

Jan. 10th Sid. Time	19h 16m 17s.54
Accel. for 7h... =	1 8 .99
" 12m.. =	1 .97
" 14s .. =	.04
Red. Sid. Time.......	19h 17m 28s.54

The acceleration is taken from Table 9 Bowditch, Table 38 Norie, or from the Nautical Almanac.

Like the ordinary chronometer problem, we need to have the mean time Greenwich; the true altitude, latitude and polar distance. The star's right ascension and declination are taken out at sight from the Nautical Almanac, and require no correction.

Add together the true altitude, latitude and polar distance. Find the half sum and remainder; take out the logs, and find the hour angle, the same as with the sun.

Now, Observe. If the star is west of the meridian, add the star's right ascension to the hour angle, and you have the right ascension of meridian. (You may have to reject 24 hours.)

If the star is east of the meridian, subtract the hour angle from the star's right ascension, adding 24 hours if necessary, and the result is the right ascension of meridian. Or, you may turn the eastern hour angle into western hour angle by sub-

tracting it from 24 h, and then treat it the same as star west of meridian.

From right ascension of meridian subtract sidereal time (+ 24 h if necessary) and you have the *mean time at ship,* which must now be dated one day less than the civil date at ship if A. M. sight, but the same day if P. M. sight. The difference between the mean time ship and the mean time Greenwich is the longitude in time, which converted in the usual way, will be the longitude of the ship; *east* or *west,* according as the Greenwich time is *least* or *best,* thus ending the same as the common chronometer problem.

The following examples, like many others throughout this work, are taken from the author's own work-book, and computed afresh, using a more recent date. These star observations, taken under favorable conditions, and otherwise, compare well with the ship's position by dead reckoning, carried on from position by observation at noon.

EXAMPLE 1.

1902, January 28th, 9 h 0 m P. M. at ship; Lat. 49° 48′ N.; observed altitude star Procyon, east of meridian, 39° 20′; height of eye 26 feet; time by chronometer 27 days, 21 h 25 m 19 s, which was 1 m 35 s fast on mean time Greenwich. Required the longitude.

Chron	27d 21h 25m 19s
Err...........	— 1 35
M. T. G.....	27d 21h 23m 44s

Alt..	39° 20′ 0″
Dip.......	— 5 0
	39° 15 0″
Ref	— 1 9
T. Alt...	39° 13′ 51″

Star's R. A.
7h 34m 10s

Star's Decl. N,	
	5° 28′ 34″
	90 0 0
P. Dist	84° 31′ 26″

Sid. Time on 27d	=	20h 23m 19s
Accel. for 21h.............	=	3 26 .99
" for 23m............	=	3 .78
" for 44s	=	.12
Red. Sid. Time		20h 26m 49s.89

Alt......	39° 13′ 51s		
Lat.....	49 48 0	Sec	0.190132
P, D ...	84 31 26	Cosec......	0.001986
2)	173 33 17		
	86 46 38	Cosine.....	8.750178
	47 32 47	Sine	9.867978
H. Angle E...........	1h 57m 48s	=	8.810274
Star's R. A...........	7 34 10		
R. A. Mer............	5 36 22		
Sid. Time............	20 26 50		
M. T. S.........	28d 9 9 32		
M. T. G........	27d 21 23 44		
	11h 45m 48s	=Long.	176°27′E

EXAMPLE 2.

1902, April 29th, A. M. at ship; Lat. 30° 1′ 10″ S.; observed altitude star Altair 25° 25′ 20″ east of meridian; eye

28 feet; chronometer 28 days, 2 h 40 m 58 s, which was slow 3 m 5 s on mean time Greenwich; index error +0′ 30″. Required the longitude.

Chron........	28d 2h 40m 58s	Alt.........	25°25′20″
Slow...........	-/- 3 5	I. E.....	-/- 30
M. T. G............	28 2 44 3		25 25 50
		Dip........	— 5 11
			25 20 39
		Ref......	— 2 0
		T. Alt...	25°18′ 39″

Star's R. A.	Star's Decl.
19h 46m 0s	8° 36′ 33″ N.
	90 0 0
	P. D... 98° 36′ 33″

Alt......	25°18′ 39″		
Lat......	30 1 10	Sec	0.062542
P. D.....	98 36 33	Cosec	0.004920
	2) 153 56 22		
	76 58 11	Cosine	9.353181
	51 39 32	Sine	9.894496
H. A. E......	3h 36m 17s=		9.315139
Star's R. A...	19 46 0		
R. A. Mer..	16 9 43		
Sid. Time..	2 22 32		
M. T. S........	28d 13 47 11		
M. T. G........	28d 2 44 3		
	11h 3m 8s=Long. 165° 47′ East		

Sid. Time on 28d=	2h 22m 5s .32
Accel. for 2h=	19 .71
" " 44m=	7 .23
Red. Sid. Time...	2h 22m 32s .26

Note.—The logs are taken out to nearest half-minute of arc only.

EXAMPLES FOR PRACTICE.

1. 1902, August 8th, A. M. at ship; Lat. 49° 2′ S.; observed altitude star Fomalhaut 42° 1′ west of meridian; eye 24 feet; index error − 30″; chronometer 8 days, 2 h 12 m 55 s, which was fast on mean time Greenwich 1 m 40 s. Find the longitude.

2. 1902, January 29th, P. M. at ship; Lat. 49° 48′ N.; observed altitude star Sirius east of meridian 22° 22′; eye 30 feet; chronometer 28 day, 21 h 28 m 20 s, which was fast on mean time Greenwich 1 m 35 s; no index error. Required the longitude.

Note—The logs are all taken out to nearest half-minute of arc only.

Answers at the end of the Guide.

POSITION BY SUMNER.

The ship's position by Sumner is found by assuming two latitudes approximating the true latitude, and with these assumed latitudes, finding the corresponding longitude from each

of two separate altitudes, and the chronometer times when these altitudes were taken.

Should the ship remain stationary during the interval between the observations, the lines joining the positions found by each altitude cross at the ship's position; but if the ship has changed her place during the interval, the first line of position will have to be carried forward to the end of the run.

Let the assumed latitudes not be too far apart, nor far from the true latitude; for remember that the lines joining the two positions obtained from each altitude represent a small part of a circle on the earth's surface of large diameter. If the arc of this circle intercepted between the true and assumed latitudes is small, it will not differ materially from a straight line. These lines of position being small parts of a circle on the earth's surface from which the sun has the same altitude at that instant, the sun must be in the center of that circle, and will bear at right angles to the tangent at any point on the circle, and therefore at right angles to the line of position.

In practice, it is well not to make the second observation until the sun has changed its bearing considerably; otherwise, the line of position on the chart will cut indefinitely, and give an uncertain position.

RULES.

1. Take out and correct the sun's declination and equation of time for each Greenwich time of observation.

2. Find the polar distance at each time of observation, and the true altitude of the sun's center.

3. Now, with the above, work out four longitudes as in the common chronometer question, as follows:

4. First—Mean time Greenwich and equation of time and declination at that time with the first altitude.

5. Second—Mean time Greenwich and equation of time and declination at that time with the second altitude.

EXAMPLE.

1902, May 4th, A. M. at ship; time by chronometer May 3 d 22 h 13 m 47 s mean time Greenwich; observed altitude sun's lower limb 45° 12′ 5″. Again, P. M. same day, time by chronometer May 4 d 1 h 31 m 27 s mean time Greenwich; observed altitude sun's lower limb 51° 40′ 10″; eye 16 feet;

ship's run in the interval 34 miles N.E.×E. true. Required the line of position at the time of each observation, and also the sun's true bearing, and ship's position at time of second observation. Assumed latitudes 51° N. and 51° 30′ N.

1st M. T. G.	1st Decl. N. incr.	H. Var.	1st Equ. of T. incr.	H. Var.	1st Alt.
May 3d 22h 13m 47s	15° 28' 32"	— 44".5	3m 8s.5 —	s .28	45° 12' 5"
	+ 16 28	22 .2	6 .2	2 2.2	Dip — 3 55
	Cor. decl. 15 45 0	890	3m 14s.7	17 76	45 8 10
	90 0 0	890		44 4	Corr. — 51
		890	— from App. Time	6.216	45 7 19
	P. D. 74° 15' 0"	6,0) 98,7.90			S. dia. + 15 53
		16' 28"			T. Alt. 45° 23' 12"

2nd M. T. G.	2nd Decl. N. incr.	H. Var.	2nd Equ. of T. inc.	H. Var.	2nd Alt.
4d 1h 31m 27s	15° 46' 13"	— 43".9	3m 15s —	s .26	51° 40' 10"
	+ 1 6	1.5	+ .4	1.5	Dip — 3 55
	Cor. decl. 15 47 19	2195	3m 15s.4	13 0	51 36 15
	90 0 0	439		26	Corr. — 40
	P. D. 74° 12' 41	6,0) 6,5.85	— from App. Time	.390	51 35 35
		1' 6"			S. dia. + 15 53
					T. Alt. 51° 51' 28"

FIRST LONGITUDE

Alt.	45°	23'	12"	
Lat.	51	0	0	0.201128
P.D.	74	15	0	0.016619
	2)170	38	12	
	85	19	6	8.911949
	39	55	54	9.807465
	2h	16m	51s	=8.937161
	24	0	0	
A.T.S. 3d	21	43	9	
	—	3	15	
M.T.S. 3	21	39	54	
M.T.G. 3	22	13	47	Lat. 51° 0' 0" N.
		33m	53s	=Long. 8° 28' 15" W.

A

SECOND LONGITUDE

Alt.	45°	23'	12"	
Lat.	51	30	0	0.205850
P.D.	74	15	0	0.016619
	2)171	8	12	
	85	34	6	8.888174
	40	10	54	9.809718
	2h	14m	9s	=8.920361
	24	0	0	
A.T.S. 3d	21	45	51	
	—	3	15	
M.T.S. 3d	21	42	36	
M.T.G. 3d	22	13	47	Lat. 51° 30' 0" N.
		31m	11s	=Long. 7° 47' 45" W.

B

THIRD LONGITUDE

Alt.	51°	51'	28"	
Lat.	51	0	0	0.201128
P.D.	74	12	41	0.016709
	2)177	4	9	
	88	32	4	8.408161
	36	40	36	9.776175
A.T.S. 4d	1h	13m	8s	=8.402173
	—	3	15	
M.T.S. 4	1	9	53	
M.T.G. 4	1	31	27	Lat. 51° 0' 0" N.
		21m	34s	=Long. 5° 23' 30" W.

D

FOURTH LONGITUDE

Alt.	51°	51'	28"	
Lat.	51	30	0	0.205850
P.D.	74	12	41	0.016709
	2)177	34	9	
	88	47	4	8.327016
	36	55	36	9.778708
A.T.S. 4d	1h	7m	8s	=8.328283
	—	3	15	
M.T.S. 4	1	3	53	
M.T.G. 4	1	31	27	Lat. 51° 30' 0" N.
		27m	34s	=Long. 6° 53' 30" W.

E

CHART WORK

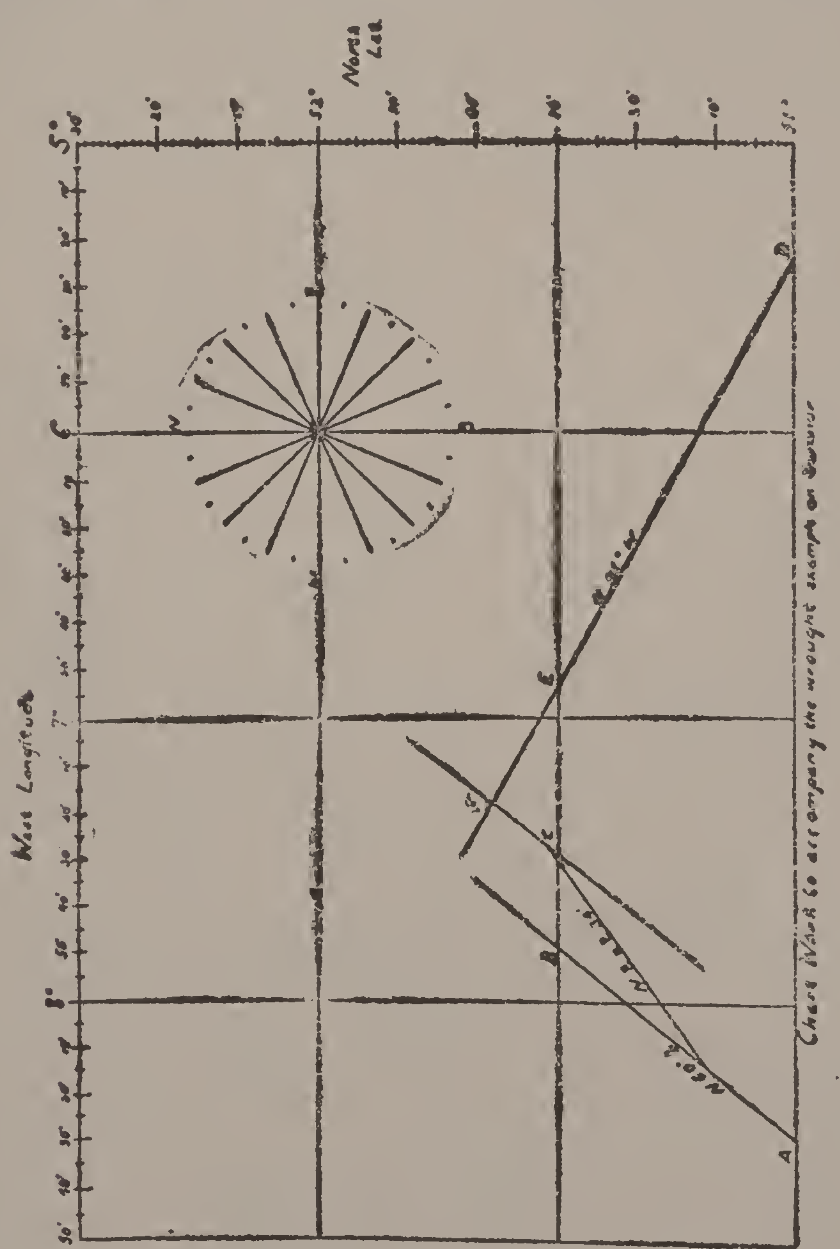
Line of position at 1st obs., N. 40° E.
Sun's true bear. at 1st obs., S. 50° E.

Line of position at 2d obs., N. 61° W.
Sun's true bear. at 2d obs., S. 29° W.

Ship's position at 2d obs. {Lat. 51° 37' 30" N. / Long. 7° 17' 30" W.}

SUMNER LINES ON THE CHART AND SUN'S TRUE BEARING.

Spot the first longitude in the work and the less assumed latitude and mark the place A. Spot the second longitude and greater assumed latitude and mark the place B. Connect the two by a neat pencil line. This is *the line of position,* and you will now note its direction, by sliding the parallel rules to the center of the nearest compass, or better still, using Field's parallel rules, you will find the line of position to the nearest degree, from one of the meridian lines on the chart. From anywhere on this line project another line representing the course and



distance the ship has gone in the interval between the first and second observation, and mark the spot arrived at C. Through C

draw a third line parallel to the first line of position. The ship will be somewhere on this line. Now, lay off the longitude found by the second altitude and less assumed latitude and call the place D. Then the longitude found by the second altitude and greater assumed latitude and name the spot E. Join D and E by a neat pencil line, and the place where this line cuts the third line you have made will be the position of the ship at the time the second observation was taken. This we will call F, and from this point take off the latitude and longitude.

The sun's true bearing is always at right angles to the line of ship's position. The bearing will be readily found if we remember that, if the ship's time is A. M., it will be easterly, and if P. M., the sun will bear westerly. The line of position is taken from 90°, and what remains is the sun's true bearing.

Suppose A. M. line of pos. N. 48° E, then the sun's
                                                    90
true bearing will be = S. 42° E.

EXAMPLES FOR PRACTICE.

1. 1902, April 5th, A. M. at ship; chronometer, April 4 d 22 h 58 m 5 s mean time Greenwich; altitude sun's lower limb 40° 12′ 10″. Again, P. M., same day; chronometer, April 5 d 1 h 58 m 10 s mean time Greenwich; altitude sun's lower limb 42° 21′ 40″; eye 22 feet; ship's run between the sights E. N. E. true 30 miles. Required line of bearing and sun's true bearing at time of first observation, and ship's position when the second observation was taken. Assumed latitudes 50° 0′ N. and 51° 0′ N.

2. 1902, October 3rd, P. M. at ship; chronometer, October 3 d 12 h 38 m 10 s mean time Greenwich; observed altitude sun's lower limb 33° 15′ 5″. Again, P. M., same day; chronometter October 3 d 14 h 52 m 3 s mean time Greenwich; observed altitude sun's lower limb 18° 12′ 40″; eye 16 feet; ship's run between sights E. N. E. true 22 miles. Required line of bearing and sun's true bearing at time of first observation, and the ship's position at time of second observation. Assumed latitudes 49° 30′ N. and 50° 0′ N.

To avoid unnecessary exactness, the logs in all these ex-

amples on Sumner are taken out to the nearest half-minute of arc only, which is sufficient for all practical purposes.

Answers at the end of the Guide.

JOHNSON'S METHOD OF DOUBLE ALTITUDES.

In the example on Sumner, given in this work, a most elaborate display of figures is presented to view, besides the accompanying chart work necessary in projecting the Sumner lines of position. Of course, it is Sumner *pure and simple.* But, as the same results can now be obtained by an easier method, introduced by that mutual friend of mariners, Mr. A. C. Johnson, it will be well to give an example or two on double altitudes, done according to the more up-to-date method. It is not always convenient to project Sumner lines on a chart; and a chart of large enough scale is not always at hand. Besides, in the Sumner, the difference in the sun's bearing between the times of observation must be, say, not less than three points, in order to insure anything like good results; whereas, with Johnson, half that difference will give splendid results. Therefore, to avoid unnecessary trouble, this latter method of double altitudes should be practiced, and the whole thing done by calculation, from first to last, in this short and approved way. The author has used this method for some years, and finds it almost indispensable.

RULE.

Two observations are taken, with an interval of 1½ or 2 hours between them, provided the sun has altered his bearing not less than 2 points.

Work out the first observation for longitude with the latitude by dead reckoning at the time of observation. Carry on this latitude by dead reckoning and the longitude just found, for the run the ship has made between the two observations, and work the second observation with this new latitude. Name the longitudes one and two. The sun's bearing for apparent time at each observation must be taken from the azimuth tables.

"Now," says Mr. Johnson (in his valuable pamphlet entitled "Cloudy Weather"), "enter Table 1* with the latitude and bearings, and take from it two numbers (*a*) and (*b*), of which take the difference, or sum, according as the bearings are in the same or different quarters of the compass. The difference of longitude divided by this difference or sum gives the correction for the second latitude and (*a*) and (*b*) multiplied by the correction for latitude give the corrections for the two longitudes."

APPLYING THE CORRECTIONS.

"When the observations are in the same quarter of the compass, allow the corrections both to the east, or both to the west, in such a manner as to make the two longitudes *agree*. When the observations are in different quarters of the compass, correct the easterly longitude towards the west, and the westerly longitude towards the east, in such a manner as to make the two longitudes *agree*. If they do not agree, they show that the corrections have been wrongly applied, and herein we have a valuable safeguard against error, peculiar to this method only. With either correction and the corresponding bearing, find the name of the correction for the latitude thus: Suppose the correction for either longitude to be west, and the corresponding bearing S. W.; writing the letters N. E. under the above, we see that the letter opposite to W. is N., which is, accordingly, the name for the correction for latitude two."

EXAMPLE 1.

1902, May 4th, A. M. at ship; time by chronometer 3 d, 22 h 13 m 47 s mean time Greenwich; observed altitude sun's lower limb 45° 12′ 5″. Again, P. M., same day; time by chronometer 4 days, 1 h 31 m 27 s mean time Greenwich; observed altitude sun's lower limb 51° 40′ 10″; height of eye 16 feet; latitude by dead reckoning 51° 15′ N.; ship's run between the observations was 34 miles N. E. × E. true. Required the latitude and longitude at time of second observation.

* Table 1 is found in Johnson's "Cloudy Weather," a little pamphlet every navigator should possess.

Note.—This is the same example given on page 66 under Sumner, and it is here worked by Johnson's method to show the astonishing decrease in figures with the same result.

FIRST OBSERVATION A. M.

M. T. G.	Alt.	Decl. N. incr	H. Var.	Equ. T. incr.	H. Var.
3d 22h 13m 47s	45° 12′ 5″	15° 28′ 32″	44″.5	3m 8s.5	s.28
	− 3 55	+ 16 28	22 .2	+ 6 .2	22.2
	45 8 10	15 45 0	890	3m 14s.7	1776
	− 51	90 0 0	890		444
			890	— from app. time	
	45 7 19	P. D. 74° 15′ 0″	6,0) 98.7.90		6.216
	+ 15 53		16′ 28″		
T. Alt.	45° 23′ 12″				

Alt. 45° 23′ 12″
Lat. 51 15 0 — 0. 203479
P.D. 74 15 0 — 0. 016619
170 53 12
85 26 36 — 8. 900225
40 3 24 — 9. 808594
H. Ang. 2h 15m 31s — .8. 928917
24
A.T.S. 3d 21 44 29
Equ.T.— 3 15
M,T.S. 3d 21 41 14
M.T.G. 3d 22 13 47
Long. in time 32m 33s = Long. 8° 8′ 15″ W
d. long. 46 15 E.
Long. [1] 7° 22′ 0″ W.

N. E.
N. 5 pts. E. 34′ = 18.9 — 28.3 = 46′¼
51° 15 N.
51° 34′ N.

Sun's bearing 9h 44m A. M. N. 130° E.
180
S. 50° E. = 1.33
N. W.

Long. [1] 7° 22′ 0″ W.
Corr. — 4 30
Long. 7° 17′ 30″ W. at 2nd obs.

SECOND OBSERVATION P. M.

M. T. G.	Alt.	Decl. N. incr.	H. Var.	Equ. T. incr.	H. Var.
4d 1h 31m 27s	51° 40′ 10″	15° 46′ 13″	43″.9	3m 15s	.26
	— 3 55	+ 1 6	1 .5		1-5
	51 36 15	15 47 19	2195	— from app. time	130
	40	90 0 0	439		26
	51 35 35	P.D. 74° 12′ 41″	6,0) 6,5.85		390
	+ 15 53		1′ 6″		
T. Alt..	51° 51 28				

Alt.......... 51° 51′ 28″
Lat.......... 51 34 0 . 0 . 206486
P. D........ 74 12 41 . 0 . 016709
177 38 9
88 49 4 . 8 . 314954
36 57 36 . 9 . 779044
A. T. S.......... 4d 1h 6m 16s . 8 . 317193
Equ. T.......... — 3 15
M. T. S......... 4 1 3 1
M. T. G......... 4 1 31 27
Long. in time 28m 26s = Long. [2] 7° 6′ 30 W
11
Longitude 7° 17′ 30″ West at 2nd obs.

Sun's bearing 1h 6m P. M. N 154° W
180
S 26° W=3.23
N E

Lat.... 51° 34′ N
Corr.... 3 30″ N
Corrected Lat..... 51° 37′ 30″ North at 2nd obs.

(*a*) S 50° E = 1.33 Long. [1] 7° 22′ .0
(*b*) S 26 W = 3.23 Long. [2] 7° 6′ .5
4.56) 15.50 (3′.4
1368
1820

(*a*)	(*b*)
1.33	3.23
3.4	3.4
532	1292
399	969
4.522	10.982

AS PRACTICED DAILY BY THE AUTHOR AT SEA.

First observation, Thursday, January 30th, 8 h 49 m A. M. by clock; Pat. log 65′; eye 30 feet; latitude, dead reckoning, 51° 15′ N.

Chron. U.	Alt. L. L.	Decl.S. decr.	H. Var.	Equ. T. incr.	H. Var.
30d 8h 51m 51s	9°13′0″	17°49′48″	40″.7	13m 23s	0s .42
Fast — 1 34	— 5 22	— 5 58	8 .8	+ 4	8 .8
M. T. G... 30d 8h 50m 17s	9 7 38	17 43 50	3256	13m 27s	336
	— 5 34	90 0 0	3256	+ to app. time	336
	9 2 4	107°43′50″	6,0) 35,8.16		3,696
	+ 16 15		5′58″		
	T.Alt. 9°18′19″				

Alt...... 9°18′19″
Lat...... 51 15 0 — 203479
P. D..... 107 43 50 — 021142
168 17 9
84 8 34 9 . 008894
74 50 15 9 . 984603
A.T.S. 29d 20h 48m 7s 9 . 218118
Equ.T. + 13 27
M.T.S. 29 21 1 34
M.T.G. 30 8 50 17
11h 48m 43s

N. 75° E. 18′ = 4 .7—17.4 = 28′ E
Lat. [1] 51° 15′ N. 177 10 45 W
Lat. [2] 51° 19′ 42″ Long. [1] 176°42′45″ W

Sun's Azim. N 134° E
180
S 46 E = 1.53
N W

Long. 177° 10′ 45″ W
28 E
Long. [1] 176 42 45 W
Corr. 14 0 W
Longitude 176° 56′ 45″ West.

Second observation, about 10 h 32 m A. M. Log 83′—65′ = 18′ N. 75° E.

Same Chron.	Alt. L. L.	Decl.S. decr.	H. Var.	Equ. T. incr.	H. Var.
30d 10h 33m 36s	18°15′0″	17°49′48″	40″.7	13m 23s	0s .42
Fast...... — 1 34	— 5 22	— 7 7	10 .5	4	10 .5
M.T.G... 30d 10h 32m 2s	18 9 38	17 42 41	2035	13m 27s	210
	— 2 44	90 0 0	407	+ to app. T.	420
	18 6 54	107°42′41″	6,0) 42,7.35		4.410
	+ 16 15		7′ 7″		
	T.Alt. 18°23′9″				

Alt..... 18° 23′ 9″
Lat..... 51 19 42 — 204188
P. D... 107 42 41 — 021082
177 25 32
88 42 46 8 . 350181
70 19 37 9 . 973875
A. T. S...... 29d 22h 33m 13s = 8 . 549326
Equ. T...... + 13 27
M. T. S..... 29 22 46 40
M.. T G..... 30 10 32 2
11h 45m 22s = Long. [2] 176° 20′ 30″ W
Corr. 36 15 W
Longitude 176° 56′ 45″ West.

Sun's Azim........N 158° E
180
S 22 E = 3.94
N W

Lat............ [2] 51° 19′ 42″ N
Corr... 9 12 S
Latitude.... 51° 10′ 30″ North.

(*a*) S 46° E = 1.53 Long. [1] 176° 42′ .75
(*b*) S 22 E = 3.94 Long. [2] 176 20 .50
2.41) 22 .25 (9.2
21 69
560

(*a*) 1.53
9.2
306
1377
14,076

(*b*) 3.94
9.2
788
3546
36,248

Logs are taken out to nearest half min. of arc.

EXAMPLE FOR PRACTICE.

1902, January 27th, 9 h 20 m A. M. by clock; latitude by account 46° 44′ N.; chronometer 26 days, 10 h 32 m 7 s

mean time Greenwich; altitude sun's lower limb 14° 15′. Again, same day, about 10 h 46 m A. M.; chronometter 26 days, 12 h 4 m 18 s mean time Greenwich; altitude sun's lower limb 22° 11′; eye 28 feet; ship's run between sights N. 63° E. 12 miles. Required latitude and longitude at time of second observation, by Johnson's method.

Answer at the end of the Guide.

STAR TIME AZIMUTH.

We need the Greenwich time, which may be given in the example, but if not given, we must find it by applying the longitude in time; west add; east subtract; for the purpose of accelerating the sidereal time for the hours, minutes and seconds of the Greenwich date.

If mean time at ship is given, make it astronomical mean time at ship, and to it add the accelerated sidereal time to get the right ascension of meridian. From this subtract the star's right ascension, and the result is the hour angle west. If it is more than 12 hours, take it from 24 hours and name the remainder hour angle east.

If apparent time at ship be given, then, to the astronomical apparent time at ship add sun's right ascension and the result is right ascension of meridian, from which we subtract the star's right ascension to get the hour angle west. Should it exceed 12 hours, subtract from 24 hours and call result hour angle east.

Enter the azimuth tables with nearest degree of latitude and declination, and the hour angle to nearest minute in the *P. M. column.* Take out the star's true azimuth and name it north or south, as directed at the foot of the page, and east or west, as the hour angle is east or west. Then proceed to find the compass error and deviation, as with the sun's azimuth.

Note.—In each case add 24 hours or reject 24 hours, if necessary.

EXAMPLE 1.

1902, May 10th, 3 h 10 m A. M. mean time at ship; lati-

tude 60° 5′ N.; longitude 31° 12′ E.; compass bearing of star Arcturus S. 56° 15′ W.; variation 12° 7′ E. Required compass error and deviation by time azimuth tables.

M.T.S. 9d 15h 10m	Long. E. 31° 12′	Star's decl. 19° 41′ 33″ N.	Star's R. A. 14h 11m 11s
— 2 5	4		
M.T.G. 9 13 5	60)124 48		
	2h 4m 48s		

True Azim. N.	105°	15′	W.
	180		
True ....S	74	45	W.
Comp. ......S	56	15	W.
Error.........	18	30	E.
Var	12	7	E.
Deviation.....	6°	23′	E.

Sid. Time 9th =	3h	5m	27s
Accel. for 13h =		2	8
Accel. for 5m =			1
Red. Sid Time	3h	7m	36s
M. T. S........	15	10	0
R. A. Mer......	18	17	36
Star's R. A....	14	11	11
Hour Angle W.	4h	6m	25s

EXAMPLE 2.

1902, October 21st, 11 h 10 m P. M. mean time ship; Lat. 31° 10′ S.; Long. 123° 4″ W.; star Algenib bore by compass N. 52° 55′ W.; variation 13° 59′ E. Required compass errror and deviation.

	d h m
M. T. S.......	21 11 10
	-/- 8 12 16
	d h m s
M. T. G	21 19 22 16

Long. 123° 4′ W
4
6,0)49,2 16
8h 12m 16s

Star's decl. 14°38′19″ N

Star's R.A. h m s 0 8 11

Sid. Time... 21st=	13h	55m	59s
Accd. for.... 10h=		3	7
" " ... 22m=			4
Red. Sid. Time	13h	59m	10s

M. T. S.	11h	10m	0s
Sid. T...	13	59	10
R.A. Mer.	1	9	10
Star's R. A..	0	8	11
H. A. W.....	1h	0m	59s

T. Azim.	S 160°W
	180
True	N 20 W
Comp.	N 52°55′W
Error	32 55 E
Var..	13 59 E
Variation	18°56′ E

EXAMPLES FOR PRACTICE.

1. 1902, October 20th, 4 h 2 m A. M. apparent time at ship; Lat. 54° 54′ S.; Long. 96° 56′ E.; star Sirius bore by compass N. 3° 40′ W.; variation 9° 50′ E. Required compass error and deviation by the azimuth tables.

2. 1902, January 18th, 7 h 5 m 30 s mean time Greenwich; Lat. 39° 48′ S.; Long. 21° 10′ E.; star a Arietis bearing N. 35° 30′ W. by compass; variation 13° 10′ E. Find the error of compass and deviation by the time azimuth tables.

Answers at the end of the Guide.

(For Lat. by Mer. Alt. of the Moon, see page 117.)

ON THE CHART.

The Sides of a Chart. The north side of a chart is usually known by a decoration of some kind at the north end of the needle of any compass printed thereon. Letters and figures are generally printed with their heads toward the north. In using the chart, therefore, the north side is to be considered the top, the right-hand side east, the left west, and the bottom south. See to this when a strange chart is placed before you, before attempting to use it.

Meridians. The lines running due north and south are called meridians. The side meridians marked with degrees and minutes are called *graduated meridians,* and are used for measuring latitude and distance.

Parallels. The lines running east and west are called parallels of latitude. Those at the top and bottom marked with degrees and minutes are termed *graduated parallels,* and are used for measuring longitude.

Latitude. To tell the latitude of a place we must see the degree or degree and minute at the side directly opposite the place. To spot a given latitude on the chart, we must see that we put the position directly opposite the latitude given. If the latitude degrees increase upwards, the latitude is north, and the chart represents part of the northern hemisphere. If the latitude degrees increase downwards, the latitude is south, and the chart represents part of the southern hemisphere.

Longitude. To tell the longitude of a place, we must see the degree or degree and minute at the top or bottom directly above or below the place. To spot a given longitude on the chart, we must see that we put the position directly above or below the longitude given. Longitude increases from 0° to 180°. When the degrees of longitude on a chart increase toward the right, the longitude is east; but if they increase to the left, the longitude is west; and this rule applies in both hemispheres, the top of the chart being north in both cases. If the meridian of Greenwich, longitude 0°, is on your chart,

the longitude to the right of it will be east, and to the left west longitude. If the 180° meridian is on your chart, the longitude to the right of it will be west, and to the left east.

Latitude and Longitude Given to Spot Position on Chart. Lay the edge of the parallel rules along the parallel of latitude on the chart next below the latitude given. Slide them up, preserving their direction, till they reach the exact latitude given. Now take the given longitude in the dividers from the top or bottom, fix one leg on a meridian near the given longitude and the other on the longitude along the edge of the parallel rules, exactly as it was taken from the top or bottom of the chart. Where the second leg falls will be the ship's position.

Finding the Course Between Two Places. Lay the edge of the parallel rules over the places; slide the rules (retaining their direction) to the center of the nearest compass, and there read off the course, true or magnetic, as the chart compass is true or magnetic.

Measuring the Distance. Take half the distance between the places in a pair of dividers, place one leg on the side of the chart at the middle latitude of the places and count the miles the other leg will reach north and south. This will be the required distance.

Find the Latitude and Longitude of a Given Spot on the Chart. Lay the edge of the rules along the parallel of latitude next below the given spot, so that if possible, the ends will reach the graduated meridian at the side. Now slide the rules till they touch the given spot. The latitude may now be read from the side of the chart, and the longitude must be measured with the dividers along the edge of the parallel rules, and transferred for reading, to the graduated parallel directly above or below. This is called Finding the Position.

Laying Off Bearings. Lay the edge of the rules over the center of the nearest compass touching the bearing given. Slide the rules carefully, preserving their direction, till the edge is over the given point, and project a faint line along the edge out from the point, opposite to the bearing. The ship is somewhere on that line, and if we lay off the bearing of some other point in the vicinity, considerably angled to the first, then

where the second line cuts the first, will be the position of the ship.

Notes.—The small numbers placed about a chart indicate the depths of water in fathoms, unless otherwise stated, at low water ordinary spring tides; and the small letters show the kind of bottom. The Roman numerals occasionally seen on charts, near the coasts, and in harbors, indicate the time of high water at full and change of the moon at that place; and in the absence of any special tables, the approximate time of high water can be obtained by these numerals as follows. Add to the chart numerals 49 minutes for every day elapsed since full or change of the moon, and the sum will be the P. M. high water approximately, for that day.

When a strange chart is placed before you, be prompt to notice whether the compasses printed thereon are true or magnetic. On some charts, both are combined. The north and south lines of a true compass will run parallel with the meridians, but the north and south line of a magnetic compass will be more or less angled to the meridians, depending on the amount of local variation; and where no variation exists, the north and south line of a magnetic compass will, like the true compass, run parallel with the meridians.

When a magnetic course is taken from the chart, the deviation, if any for the direction of the ship's head must be applied, in order to obtain the course to steer by the ship's compass, allowing easterly deviation to the left, and westerly to the right; the very opposite to what you would do when allowing the deviation on a compass course or bearing to get the magnetic.

When a true course is taken from a chart, the local variation must be allowed, easterly to the left and westerly to the right; this will give the magnetic course; and, if there is no deviation, this will be the course to steer by the compass; but if deviation exists, as in all likelihood it will on iron vessels, this, too must be allowed before we have the proper compass course. Remember that variation and deviation are allowed the same way. Easterly variation allowed to the left and westerly to the right brings a true course to a magnetic course;

and in like manner easterly deviation allowed to the left, and westerly to the right, brings a magnetic course to a compass course.

A compass couse, or bearing needs correcting for deviation (if any) to make it magnetic; easterly to the right and westerly to the left; and if we want to bring it to a true course, or bearing, we must also allow the variation, easterly to the right, westerly to the left. When a true course is found by Mercator's sailing, we must allow the variation and the deviation (if any) to reduce it to a compass course, in the same manner as if it were a true course taken from the chart, easterly to left, westerly to right, as shown above.

GREAT CIRCLE SAILING.

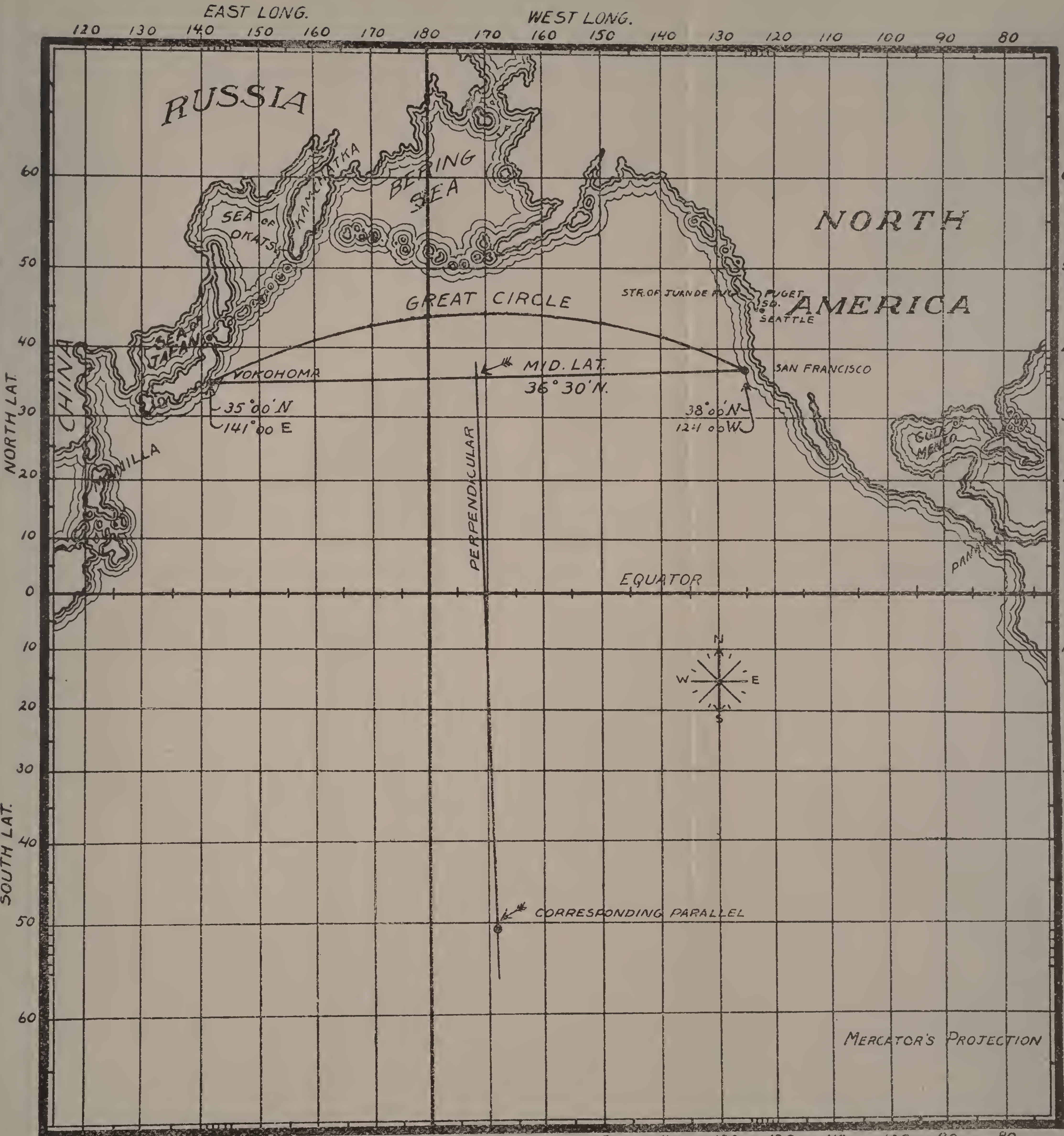
Without going into the principles of Great Circle sailing, or showing figures enough in the computation of this valuable problem, to make the ordinary, every-day navigator "say things," the writer has thought it more to the purpose to introduce, in this part of the work the late Professor Airy's short and useful method for sweeping an arc of a Great Circle on a Mercator's chart, which includes the neat little table shown below.

RULE.

1. "Join the two points, between which it is required to project the Great Circle, by a straight line. Bisect this line, and from the point of section erect a perpendicular to the line on the side next the equator, continuing it if necessary beyond the equator."

2. "With the middle latitude (between the two places) enter the following table, and take out the 'corresponding parallel.' "

3. "The center of the arc of the Great Circle, required to be drawn, will be the intersection of this parallel with the perpendicular."



GREAT CIRCLE SAILING, PGE.80

Professor Airy's table for drawing arcs of Great Circles on a Mercator's chart:

Middle Lat.	Corr. Parallel.	
20°	81° 13'	Opposite name to Lat. of points.
22	78 16	
24	74 59	
26	71 26	
28	67 38	
30	63 37	
32	59 25	
34	55 5	
36	50 36	
38	46 0	
40	41 18	
42	36 31	
44	31 38	
46	26 42	
48	21 42	
50	16 39	
52	11 33	
54	6 24	
56	1 13	

Middle Lat.	Corr. Parallel.	
58°	4° 0'	Same name as Lat. of Points
60	9 15	
62	14 32	
64	19 50	
66	25 9	
68	30 30	
70	35 52	
72	41 14	
74	46 37	
76	52 1	
78	57 25	
80	62 51	

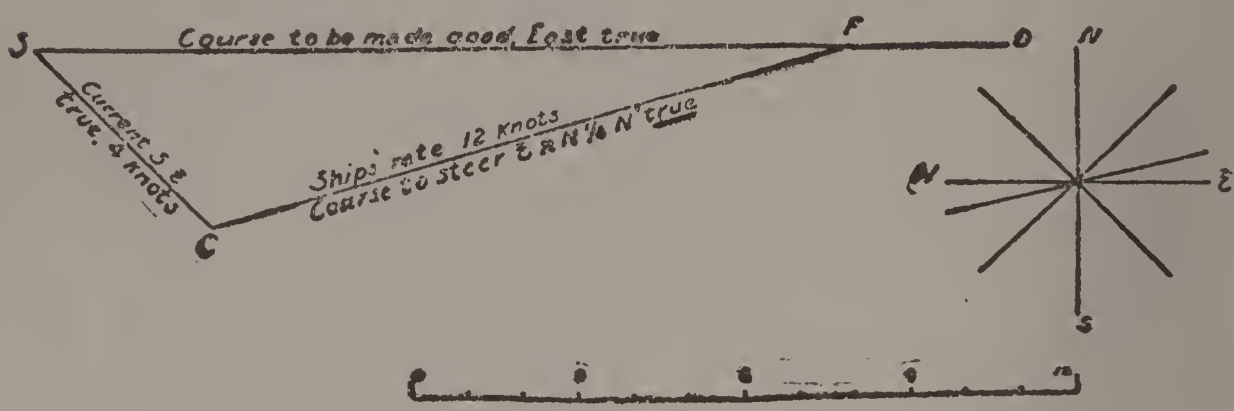
Navigators are grateful to the late Prof. Airy for these rules and table, which are considered the best known on the subject.

CURRENT SAILING.

Steering to Counteract a Known Current. Spot the ship's position on the chart, and from this point draw a pencil line representing the course you wish to make good, from the same *position* point, draw another line in the direction the current sets, also mark the distance it will set in one hour on this line; take in the dividers the distance the ship will travel in one hour, place one leg at the mark on the current line, and mark the spot where the other leg will fall on the course you wish to make good; a line joining these two marks will be the course on which to keep the ship to counteract the current. If a magnetic course, it must be corrected for deviation to make it a compass course.

Example. Let S in the diagram represent the ship's position, D her destination, and the line connecting these the course to be made good. Lay off from S the rate and set of current per hour and call this C; then take in the dividers the

run of the ship for one hour; place one leg at C and mark the spot F where the other leg falls on the line S-D. A line join-



ing C and F will represent the true course to steer to make good the course intended.

DEFINITIONS.

The applicant for his first ocean license may be required to give in writing a number of the following definitions, according to the discretion of the inspector:

1. *The Equator.* The great circle supposed to be drawn round the earth 90° from the poles.

2. *The Poles.* The ends of the axis of the earth.

3. *A Meridian.* A great circle passing through the poles, cutting the equator at right angles.

4. *The Ecliptic.* The great circle which the sun appears to describe annually in the heavens.

5. *The Tropics.* The parallels of latitude about 23° 28′ north and south of the equator.

6. *Latitude.* The distance of any place north or south of the equator, measured on a meridian.

7. *Parallels of Latitude.* Smaller circles parallel to the equator.

8. *Longitude.* The distance of any place east or west of the first meridian, measured on the equator.

9. *The Visible Horizon.* The circle where the sea and sky appear to meet.

10. *The Sensible Horizon.* The plane touching the

earth where the observer stands, and extending to the heavens.

11. *The Rational Horizon.* The plane passing through the center of the earth parallel to the sensible horizon.

12. *Artificial Horizon and Its Use.* A reflector, the surface of which is perfectly level. It is used for observing altitudes.

13. *True Course of a Ship.* The angle between the ship's track and the true meridian.

14. *Magnetic Course.* The angle between the ship's track and the magnetic meridian.

15. *Compass Course.* The track of a ship as shown by the compass.

16. *Variation of the Compass.* The angle between the true and magnetic meridians.

17. *Deviation of the Compass.* The deflection of the compass needle to the right or left of the magnetic meridian.

18. *Error of Compass.* The deflection of the compass needle to the right or left of the true meridian.

19. *Leeway.* The angle between the ship's track through the water and her fore and aft line.

20. *Meridian Altitude of a Celestial Object.* The angular height of an object above the horizon when it is on the meridian.

21. *Azimuth.* The arc of the horizon between the north and south points, and a vertical circle passing through the object.

22. *Amplitude.* The arc of the horizon between the east point and the object when rising, or the west point and the object when setting.

23. *Declination.* The distance of an object north or south of the heavenly equator.

24. *Polar Distance.* The distance of an object from the pole of the observer.

25. *Right Ascension.* The angle at the pole between the meridian passing through the object and the meridian passing through the first point of Aries.

26. *Dip or Depression of the Horizon.* The depression of the visible horizon below the level of the sensible horizon.

27. *Refraction.* The bending of the rays of light as they pass through the atmosphere.

28. *Parallax.* The angle at the center of a heavenly object subtended by the radius of the earth at the position of the observer.

29. *Semi-diameter.* The angle at the eye of the observer subtended by the radius of the object.

30. *Augmentation of the Moon's Semi-diameter.* The difference between the semi-diameter when observed in the horizon and when in altitude.

31. *Observed Altitude.* The angular height of an object as observed with an instrument.

32. *Apparent Altitude.* The observed altitude corrected for dip and semi-diameter.

33. *True Altitude.* The angular height of the center of an object above the rational horizon.

34. *Zenith Distance.* The arc of a vertical circle between the object and the zenith of the observer.

35. *Vertical Circles.* Great circles passing through the zenith, cutting the horizon at right angles.

36. *Prime Vertical.* The vertical circle passing through the east and west points of the horizon.

37. *Civil Time.* Time in common use; the day commencing at midnight and terminating at the following midnight.

38. *Astronomical Time.* Time used in astronomical calculations; the day commencing at noon and terminating at the following noon.

39. *Sidereal Time.* The westerly hour angle of the first point of Aries.

40. *Mean Time.* The westerly hour angle of the mean sun.

41. *Apparent Time.* The westerly hour angle of the true sun.

42. *Equation of Time.* The difference between mean and apparent time.

43. *Hour Angle of a Celestial Object.* The angle at the pole between the meridian of the observer and the meridian passing through the object.

44. *Compliment of an Arc or Angle.* The difference between the arc or angle and 90°.

45. *Supplement of an Arc or Angle.* The difference between the arc or angle and 180°.

46. *Great Circles.* Any circle which divides a sphere into two equal parts.

47. *Vertex of a Great Circle.* That part of the great circle farthest from the equator.

48. *Small Circles.* A circle which divides a sphere into two unequal parts.

49. *Right Angle.* The inclination of two lines, one perpendicular to the other, meeting at a point = 90°.

50. *Oblique Angle.* Any angle except a right angle.

51. *Obtuse Angle.* Any angle exceeding 90°.

52. *Arc.* A portion of the circumference of a circle.

53. *Equinoctial.* Celestial equator; it is the earth's equator extended to the celestial concave.

54. *Difference of Latitude.* The distance a ship sails north or south.

55. *Meridional Parts.* The length of the enlarged meridians on a Mercator's chart in miles of the equator for every minute of latitude.

56. *Departure.* The distance in nautical miles that a ship sails true east or west.

57. *Nautical Mile.* The mean length of a minute of latitude = 6080 feet.

58. *Rhumb Line.* The shortest line which can join two places, cutting all the meridians at the same angle.

59. *Prime Meridian.* The Standard Meridian, from which longitude is measured.

60. *First Point of Aries.* The point where the sun cuts the equinoctial passing from south to north.

61. *Radius.* Half the diameter.

62. *Elevated Pole.* Pole nearest the observer.

63. *North Magnetic Pole.* The point to which the north end of the compass needle is directed, situated in Lat. 70° N. and Long. 97° W.

64. *South Magnetic Pole.* The point to which the south

end of the compass needle is directed, situated in Lat. 74° S. and Long. 147° E.

65. *Polaris, or Pole Star.* The star which appears nearest to the true north point of the heavens; it is situated 1° 15′ from the celestial pole.

ADJUSTMENTS OF SEXTANT.

1. What is the first adjustment of the sextant?

To set the index glass perpendicular to the plane of the instrument.

2. How is that adjustment made?

Place the index near the middle of the arc, hold the instrument face up and arc from you, look into the index glass, and if the true and reflected parts of the arc form one continuous line the index glass is perpendicular; if not, make it so by screws at the back of the index glass.

3. What is the second adjustment?

To set the horizon glass perpendicular to the plane of the instrument.

4. How do you make that adjustment?

Fix the index at nothing hold the instrument nearly horizontal, face up, look through the horizon glass at the horizon, and if the true and reflected parts of the horizon form one line the glass is perpendicular; if not, make it so by the upper screw at the back of the horizon glass.

5. What is the third adjustment?

To set the horizon glass parallel to the index glass when the index is at nothing.

6. Describe how you make the third adjustment.

Fix the index at nothing, hold the instrument vertically, look through the horizon glass at the horizon, and if the true and reflected parts of the horizon form one unbroken line, the horizon glass is parallel to the index glass; if not parallel, make it so by the lower screw at the back of the horizon glass.

7. How would you proceed if a screw be lost or broken?

I would find the index error.

8. How would you find the index error by the horizon?

Clamp the index near nothing, hold the instrument vertically, look through the horizon glass at the horizon, and bring the true and reflected parts of the horizon into one continuous line by moving the tangent screw. The reading now is the index error, to be *added,* if *off* the arc; but *subtracted,* if *on* the arc.

Note.—The inspector may desire the applicant to answer the above in writing. He will also make a practical test of the applicant in the matter of reading and setting the sextant to any given angle.

Applicants for a high-grade license may be required to state in writing.

9. How do you find the index error by the sun?

Clamp the index at about 30 minutes off the arc, hold the instrument vertically, and look at the sun; two suns will now appear, one above the other, the edges of which I must bring together by means of the tangent screw, and mark down the reading. Move the index to about 30 minutes on the arc, and bring the suns into contact again and note the reading. Subtract the less reading from the greater and divide the remainder by 2, the result is the index error to be added if the greater reading is off and subtracted if the greater reading is on the arc.

EXAMPLE.

First reading	34'.0''	off the arc.
Second reading	31 .0	on the arc.
	2) 3'.0	
Index Error	1'.30''	to add.

10. Have you any proof that these angles have been taken with reasonable accuracy?

Yes; the sum of the two readings divided by 4 should equal the sun's semi-diameter for the day the angles were taken as given in the Nautical Almanac.

EXAMPLE.

First reading	34'.0''
Second reading	31 .0
	4) 65 .0
Semi diameter	16' 15''

THE LOG LINE.

The length of a knot in feet should bear the same proportion to the number of feet in a nautical mile that the seconds run by the glass do to the seconds in an hour.

Rule.—Multiply the feet in a nautical mile by the seconds run by the glass, and divide by the seconds in one hour.

A nautical or geographical mile contains 6,080 feet.

Example.—Find the length of a knot corresponding to a 28 seconds glass:

```
                       6080 feet in a nautical mile.
                         28 seconds glass.
                      -----
                      48640
                     12160
                     ------
Secs. in 1 hr. 3600 )170240( 47 feet
                     14400   ==
                     ------
                      26240
                      25200                     Ans. 47 feet 3½ in. nearly
                      -----
                       1040
                         12 inches in a foot
                      -----
               3600 )12480( 3½ inches nearly
                      10800  ==
                      -----
                       1680
```

Short Rule.—Annex a cypher to the seconds run by the glass and divide by six; the result is the length of a knot in feet. Multiply the remainder (if any) by 2 for inches.

Example.—What is the length of a knot for a 30 seconds glass by the short rule?

```
6)300
   50 feet
```

Find the length of a knot corresponding to a 20 seconds glass by the long rule: Ans. 33 feet 9 inches nearly.

What is the length of a knot corresponding to a 30 seconds glass by the long rule? Ans. 50 feet 8 inches.

Find the length of a knot for a 26 seconds glass by the short rule: Ans. 43 feet 4 inches.

What is the length of a knot for a 28 seconds glass by the short rule? Ans. 46 feet 8 inches.

THE LEAD LINE.

The Hand Lead Line has "9 marks and 11 deeps."

The marks are as follows:

At 2 fathoms the mark is	....	Leather with two ends.
" 3 " " "	....	Leather with three ends.
" 5 " " "	....	White rag.
" 7 " " "	....	Red rag.
" 10 " " "	....	Leather with hole in it.
" 13 " " "	....	Blue rag.
" 15 " " "	....	White rag.
" 17 " " "	....	Red rag.
" 20 " " "	....	Cord with two knots.

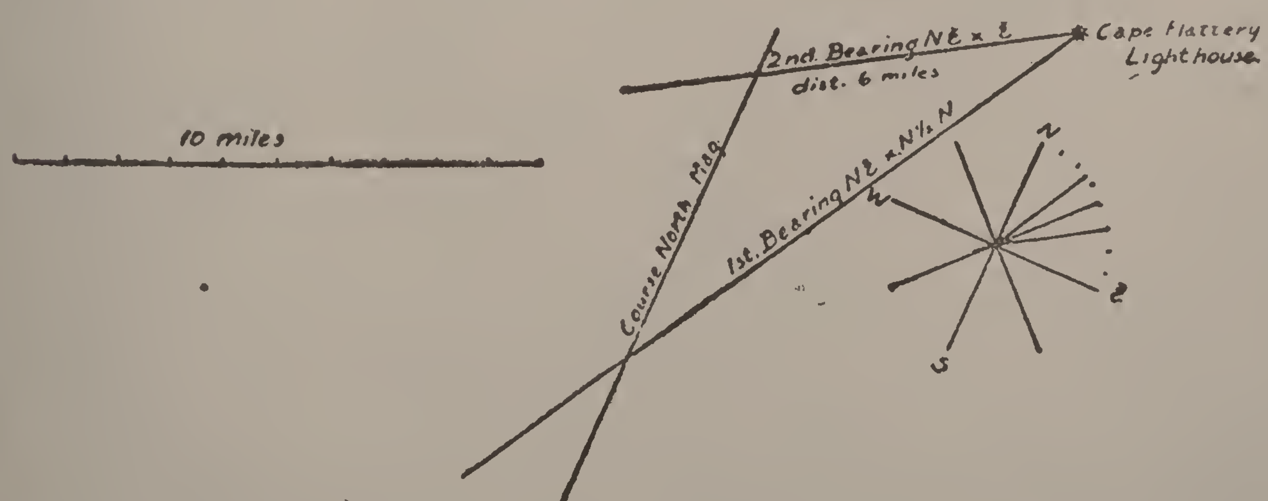
The Deep-sea Lead Line is marked the same as far as 20 fathoms, then, a piece of cord with an additional knot at every 10 fathoms; and a piece of cord with a single knot at every 5 fathoms between the tens.

DISTANCES OFF LIGHTHOUSES.

To find the approximate distance from a lighthouse or other object when steering along a coast.

Rule. Note the bearing of the object, the time by watch, and the difference between the bearing and the ship's course; continue on the course until the object's bearing has altered as much again as the difference noted. The distance from the object will now be equal to the run of the ship in the interval, making allowance for any known current or tide.

Example. 10 P. M., steamer going north by compass 12 knots an hour. Cape Flattery light bore N. E. × N. $\frac{1}{2}$ N. The



difference between this and the course north is $2\frac{1}{2}$ points. We continue on the course until 10 h 30 m P. M. when the light

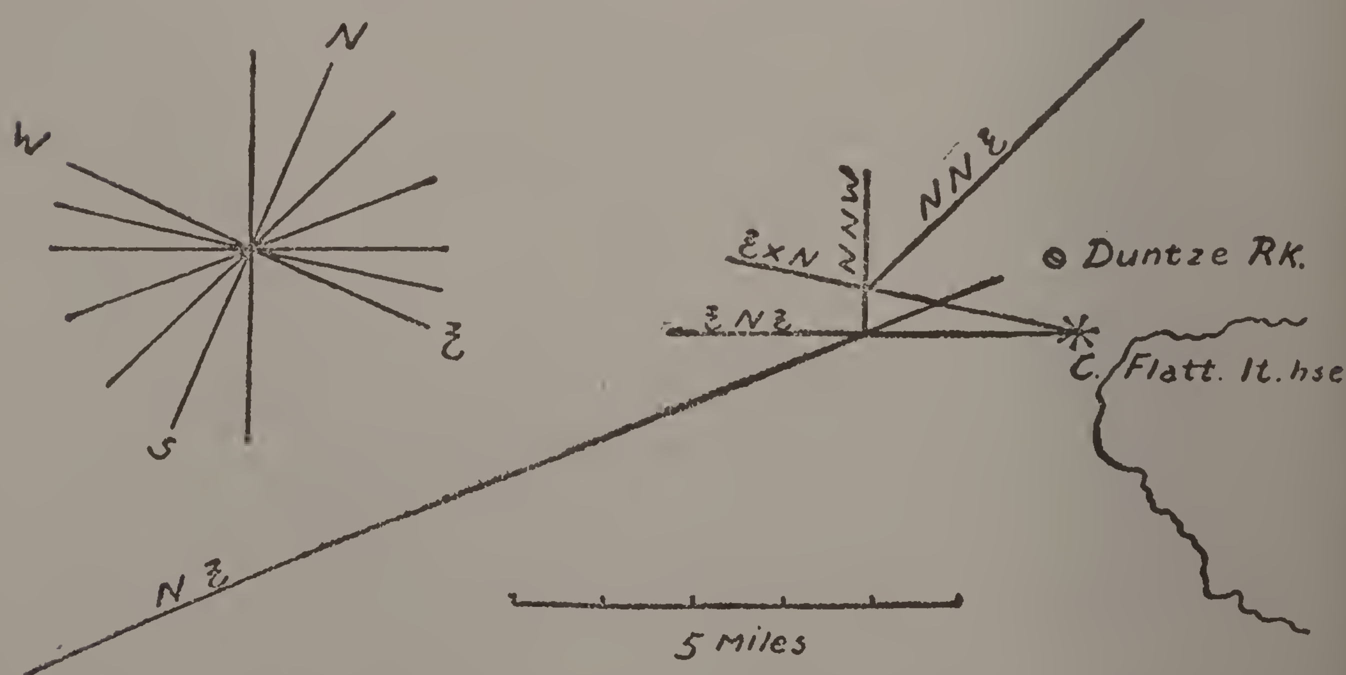
bears N. E. x E., or five points from the course. The distance off the lighthouse will now equal the distance run in the interval of one-half an hour between the bearings, namely six miles.

The course and bearings are magnetic.

Four Point Bearing. Note the reading of the log when the object is four points on the bow; continue on the same course, noting the log again when the object is abeam. The distance the ship has traveled in the interval will be the distance off. Or, knowing the rate of speed, the watch may be used instead of the log. This method is useful when taking a departure, but does not tell the distance off until you are abeam of the object.

The following method will give timely warning when approaching an object beset with outlying dangers.

Rule.—Haul the light, or day object exactly abeam, heading off, keep that course strictly until the light, or other object is exactly one point abaft the beam; now, the distance the vessel has gone in the interval, multiplied by *five,* will be the approximate distance from the light, on the last bearing. You may now set a safe course. The accompanying diagram shows the course of a ship approaching the strait of Juan de Fuca in hazy weather. She is steering N. E. magnetic, and suddenly Cape Flattery light heaves in sight bearing E. N. E., but the



distance off is a conundrum. Knowing this rule he hauls N. N. W., bringing the light right abeam; he steers thus until the light bears E. × N.; he knows his vessel's speed to be 10 knots, and

it has taken just three minutes to change the bearing of the light one point, therefore, he has traveled just half a mile; and 5 times ½ a mile make 2½ miles, the distance from the light when it was one point abaft the beam. He now sets a safe course N. N. E., passing about two miles off the light; whereas, the original course if continued, would have carried him on to Duntze Rock.

Note.—In the above cases, the navigator is not required to leave the bridge, or quarter-deck, to obtain his position, but when his position is known by the rules, he may then consult his chart for a new course, if necessary. The diagrams are simply given to prove the methods.

SOUND AND ECHOES.

Distance by Sound. Sound travels at the rate of 1090 feet per second when the air is at freezing point, or 32° Fahrenheit; and this rate is increased by 1.19 feet for every degree above that temperature giving 1123 feet (or 374 yards) per second at a mean temperature of 60°. This may be used for all ordinary purposes.

Example:—The flash of a gun was seen at	12 h 0 m 1 s.
The report was heard at	12 0 10
	9 s.

374 × 9 = 3366 yards.

Or by acceleration, thermometer at 85° Fahrenheit.

85°	at 32° Sound travels	1090	feet per second.
32	1.19 × 53 =	63	
Diff. 53°	at 85° Sound travels	1153	feet per second.

1153 × 9 = 10377 feet, or 3456 yards.

A good way to measure distance by sound is first by knowing the number of beats your watch gives in one minute. This can readily be ascertained by holding the watch close to the ear and watching with the eye a complete revolution of the second hand of a chronometer, at the same time counting the beats by the watch; 150 beats is common with good watches, or 5 beats in 2 seconds. Now, at 60° Fahrenheit, sound travels 150 yards in one beat of a watch beating 150 times per minute, therefore, that number of yards multiplied by the number of

beats between flash and report will be the distance from the gun.

Whistle Echoes From Land. We will suppose a mean temperature of 60° Fahr., at which sound travels 1123 feet per second. The echo returns in 5 seconds after the whistle commenced to sound. If we multiply 1123 feet by 5 seconds we have 5615, the number of feet the sound has covered in its round trip. Divide this by 2 and we have 2807 feet, or nearly half a mile, the distance off that part of the land from whence the echo came.

UNIFORM SYSTEM OF BUOYAGE ON PACIFIC COAST.

1. Red buoys with even numbers are placed on the starboard side of channels, and must be left on the starboard hand in passing inwards.

2. Black buoys with odd numbers are placed on the port side of channels, and must be left on the port hand in passing inwards.

3. Buoys with red and black horizontal stripes are placed on obstructions, with channels on either side, and may be left on either hand in passing inwards.

4. Buoys with white and black perpendicular stripes are placed in mid-channel, and must be passed close to to avoid danger.

5. Perches with balls, cages, etc., when placed on buoys, will be at turning points, the colors and numbers indicating on which side they should be passed.

6. Different channels in the same bay, sound, river, or harbor, are usually marked by different kinds of buoys: principal channels by nun-buoys; secondary channels by can-buoys, and minor channels by spar buoys. Where there is but one channel, nun-buoys, properly colored and numbered, are in general use to mark the starboard side; and can-buoys, properly colored and numbered, to mark the port side.

For fuller information, see "List of Beacons, Buoys and Day Marks of the Pacific Coast of the United States."

Sun's Declination and Semi-Diameter for 1900

DATE	DECLINATION	HOURLY VARIATION	SEMI-DIAMETER
JANUARY			
17	S. 20° 46′ 31″ .1	29″ .5	16′ 17″ .0
18	20 34 32 .1	30 .5	16 16 .9
28	18 14 13 .1	39 .5	16 15 .8
29	17 58 16 .2	40 .3	16 15 .7
FEBRUARY			
26	S. 8° 46′ 26″ .1	56″ .1	16′ 10″ .4
27	8 23 56 .8	56 .4	16 10 .1
MARCH			
8	S. 4° 56′ 49″ .6	58″ .4	16′ 7″ .9
9	4 33 24 .8	58 .6	16 7 .7
APRIL			
11	N. 8° 15′ 11″ .1	55″ .1	15′ 58″ .7
12	8 37 10 .2	54 .8	15 58 .4
JUNE			
3	N. 22° 17′ 44″ .2	18″ .7	15′ 47″ .3
4	22 25 0 .2	17 .7	15 47 .2
5	22 31 52 .7	16 .7	15 47 .1
JULY			
2	N. 23° 3′ 56″ .8	10″ .9	15′ 45″ .3
3	22 59 24 .2	11 .9	15 45 .3
4	22 54 27 .6	12 .9	15 45 .3
22	20 19 55 .5	29 .6	15 46 .1
23	20 7 53 .7	30 .5	15 46 .2
AUGUST			
6	N. 16° 46′ 13″ .1	41″ .1	15′ 47″ .8
7	16 29 37 .8	41 .8	15 48 .0
8	16 12 46 .7	42 .4	15 48 .1
17	13 29 57 .5	47 .8	15 49 .6
18	13 10 43 .1	48 .4	15 49 .8
SEPTEMBER			
14	N. 3° 29′ 39″ .3	57″ .6	15′ 55″ .9
15	3 6 34 .8	57 .7	15 56 .2
19	1 33 44 .3	58 .2	15 57 .2
20	1 10 25 .3	58 .3	15 57 .5
OCTOBER			
4	S. 4° 16′ 32″ .6	57″ .9	16′ 1″ .4
5	4 39 41 .9	57 .8	16 1 .6
7	5 25 49 .5	57 .5	16 2 .2
8	5 48 47 .3	57 .3	16 2 .3
12	7 19 50 .0	56 .4	16 3 .6
13	7 42 21 .9	56 .2	16 3 .9
NOVEMBER			
5	S. 15° 38′ 10″ .7	45″ .7	16′ 9″ .9
6	15 56 20 .8	45 .1	16 10 .1

NAUTICAL ALMANAC ELEMENTS FOR JANUARY, 1902

Date	Sun's Right Ascension			Hourly Diff.	Sun's Declination			Hourly Diff.	Semi-Diameter		Equation of Time. App. Add to Time		Hourly Diff.	Sidereal Time at Green. Mean Noon		
4	18 h	57 m	28.4 s	+11.01 s	S. 22°	47'	33.2"	+15.1"	16'	17.1"	4 m	49.4 s	1.15 s	18 h	52 m	38.2
5	19	1	52.4	10.99	22	41	16.9	16.2	16	17.1	5	16.8	1.13	18	56	34.8
7	19	10	39.2	10.95	22	27	23.5	18.5	16	17.0	6	10.3	1.10	19	4	27.9
8	19	15	1.9	10.93	22	19	46.8	19.6	16	17.0	6	36.4	1.07	19	8	24.4
10	19	23	45.7	10.89	22	3	14.5	21.8	16	16.9	7	27.0	1.03	19	16	17.5
11	19	28	6.8	10.87	21	54	19.4	22.8	16	16.9	7	51.4	1.01	19	20	14.1
18	19	58	16.6	10.67	20	40	14.2	30.0	16	16.5	10	24.9	.81	19	47	50.0
19	20	2	32.3	10.64	20	28	2.9	31.0	16	16.4	10	44.0	.78	19	51	46.5
26	20	32	0.8	10.41	18	52	15.1	37.3	16	15.7	12	36.3	.55	20	19	22.4
27	20	36	10.3	10.38	18	37	8.3	38.2	16	15.6	12	49.2	.52	20	23	19.0
28	20	40	19.0	10.35	18	21	41.2	39.0	16	15.4	13	1.3	.49	20	27	15.6
29	20	44	26.9	10.31	18	5	54.2	39.9	16	15.3	13	12.6	.45	20	31	12.1
30	20	48	34.0	10.28	17	49	47.7	40.7	16	15.2	13	23.1	.42	20	35	8.7
31	20	52	40.3	10.24	17	33	22.2	41.5	16	15.0	13	32.8	.39	20	39	5.2

NAUTICAL ALMANAC ELEMENTS FOR FEBRUARY, 1902

Date	Sun's Right Ascension	Hourly Difference	Sun's Declination	Hourly Diff.	Semi-diameter	Equation of Time. Add to App. Time	Hourly Diff.	Sidereal Time at Green. Mean Noon
2	21 h 0 m 50.4 s	+10.18 s	S. 16° 59' 35.1"	+43.0"	16' 14.7"	13 m 49.8 s	.32 s	20 h 46 m 58.3 s
8	21 25 1.6	9.98 s	15 11 17.0	47.1	16 13.8	14 21.6	.12	21 10 37.7
9	21 29 0.6	9.94 s	14 52 17.6	47.8	16 13.6	14 24.0	.09	21 14 34.2

NAUTICAL ALMANAC ELEMENTS FOR MARCH, 1902

Date	Sun's Right Ascension	Hourly Difference	Sun's Declination	Hourly Diff.	Semi-diameter	ADD TO APP. TIME	Hourly Diff.	Sidereal Time at Green. Mean Noon
9	23 h 15 m 52.5 s	+ 9.23 s	S. 4° 44' 40.8"	+58.5"	16' 7.4"	10 m 53.0 s	.62 s	23 h 4 m 57.7 s
10	23 19 33.9	9.22	4 21 13.8	58.7	16 7.1	10 37.9	.64	23 8 54.2
14	23 34 16.0	9.16	2 46 57.6	59.1	16 6.1	9 34.0	.69	23 24 40.5
15	23 37 55.8	9.15	2 23 18.4	59.2	16 5.8	9 17.2	.70	23 28 37.0
16	23 41 35.3	9.14	1 59 37.9	59.2	16 5.6	9 0.2	.71	23 32 33.6
21	23 59 49.6	9.10	S. 0 1 8.6	59.2	16 4.2	7 32.0	.75	23 52 16.3
22	0 3 27.9	9.10	N. 0 22 32.2	59.2	16 3 9	7 13.8	.76	23 56 12.9
29	0 28 54.6	9 09	3 7 25.7	58.5	16 2.0	5 5.0	.77	0 23 48.7
30	0 32 32.7	9 09	3 30 47.6	58.3	16 1.7	4 46.6	.76	0 27 45.3
31	0 36 10.9	9.09	3 54 5.6	58.2	16 1.4	4 28.3	.76	0 31 41.8

FROM NAUTICAL ALMANAC, APRIL, 1902

Day	Apparent Right Ascension	Hourly Diff.	Apparent Declination	Hourly Diff.	Semi-Diameter	Eq'tion of Time + to App. Time — from App. Time	Hourly Diff.	Sidereal Time at Green. Mean Noon
2	0 h 43 m 27.6 s	+ 9.10 s	N. 4° 40' 28.4"	+57.8"	16' 00.9"	3 m 52.0	.75 s	0 h 39 m 34.9 s
3	0 47 6.1	9.11	5 3 32.6	57.6	16 00.6	3 34.1	.75	0 43 31.5
4	0 50 44.8	9.12	5 26 31.5	57.3	16 00.3	3 16.2	.74	0 47 28.1
5	0 54 23.7	9.12	5 49 24.8	57.1	16 00.1	2 58.6	.73	0 51 24.6
6	0 58 2.7	9.13	6 12 12.0	56.8	15 59.8	2 41.1	.72	0 55 21.2
7	1 1 41.9	9.14	6 34 52.8	56.6	15 59.5	2 23.8	.71	0 59 17.7
10	1 12 41.0	9.17	7 42 13.4	55.6	15 58.7	1 33.4	.69	1 11 7.4
11	1 16 21.1	9.18	8 4 25.2	55.3	15 58.4	1 17.0	.67	1 15 3.9
28	2 19 37.0	9.46	13 56 23.1	47.6	15 54.0	2 27.9	.40	2 22 5.3
29	2 23 24.3	9.48	14 15 17.6	47.0	15 53.8	2 37.1	.37	2 26 1.9

FROM NAUTICAL ALMANAC, MAY, 1902

Day	Apparent Right Ascension	Hourly Diff.	Apparent Declination	Hourly Diff.	Semi-Diameter	Eq'tion of Time	Hourly Diff.	Sidereal Time at Green. Mean Noon
3	2 h 38 m 39.0 s	+ 9.57 s	N. 15° 28' 31.8"	+44.5"	15' 52.8	3 m 8.5	.28	2 h 41 m 48.1
4	2 42 29.1	9.60	15 46 13.1	43.9	15 52.6	3 15.0	.26	2 45 44.6
5	2 46 19.7	9.62	16 3 38.8	43.2	15 52.4	3 20.9	.23	2 49 41.2
6	2 50 10.9	9.65	16 20 48.5	42.6	15 52.1	3 26.2	.21	2 53 37.7
7	2 54 2.7	9.67	16 37 41.9	41.9	15 51.9	3 31.0	.19	2 57 34.3
9	3 1 48.0	9.72	17 10 38.9	40.5	15 51.5	3 38.8	.14	3 5 27.4
10	3 5 41.5	9.74	17 26 41.7	39.8	15 51.2	3 41.8	.12	3 9 24.0
11	3 9 35.6	9.76	17 42 27.2	39.0	15 51.0	3 44.4	.09	3 13 20.5
12	3 13 30.2	9.79	17 57 54.7	38.3	15 50.8	3 46.3	.07	3 17 17.1
13	3 17 25.3	9.81	18 13 4.2	37.5	15 50.6	3 47.7	.05	3 21 13.6
27	4 13 15.1	10.12	21 11 4.5	25.7	15 48.0	3 9.8	.27	4 16 25.4

NAUTICAL ALMANAC ELEMENTS FOR JUNE, 1902

Date	Sun's Right Ascension.	Hourly Diff.	Sun's Declination	Hourly Diff.	Semi-Diameter	Equation of Time. Sub. from App. Time	Hourly Diff.	Sidereal Time at Green. Mean Noon
4	4 h 45 m 53.8 s	+10.27 s	N. 22° 21' 24.9"	—18.1"	15' 46.9"	2 m 3.7 s	.41 s	4 h 47 m 57.9 s
5	4 50 0.5	10.29	22 28 28.9	17.2	15 46.8	1 53.6	.43	4 51 54.4
6	4 54 7.6	10.30	22 35 9.4	16.2	15 46.7	1 43.1	.44	4 55 51.0

NAUTICAL ALMANAC ELEMENTS FOR JULY, 1902

ADD TO APP. TIME

Date	Sun's Right Ascension.	Hourly Diff.	Sun's Declination	Hourly Diff.	Semi-Diameter	Equation of Time	Hourly Diff.	Sidereal Time at Green. Mean Noon
5	6 h 54 m 22.6 s	+10.31 s	N. 22° 51' 39.5"	—13.4"	15' 45.0"	4 m 10.8 s	.45 s	6 h 50 m 11.1 s
6	6 58 29.8	10.29	22 46 6.3	14.4	15 45.0	4 21.4	.43	6 54 7.7
7	7 2 36.6	10.28	22 40 9.4	15.4	15 45.0	4 31.6	.42	6 58 4.2
15	7 35 16.3	10.13	21 38 40.4	23.0	15 45.3	5 38.6	.27	7 29 35.7
16	7 39 19.1	10.11	21 29 17.7	23.9	15 45.3	5 44.9	.25	7 33 33.2
24	8 11 22.3	9.92	20 1 25.2	30.9	15 45.9	6 15.6	.07	8 5 5.7

NAUTICAL ALMANAC ELEMENTS FOR AUGUST, 1902

ADD TO APP. TIME

Date	Sun's Right Ascension.	Hourly Diff.	Sun's Declination	Hourly Diff.	Semi-Diameter	Equation of Time	Hourly Diff.	Sidereal Time at Green. Mean Noon
8	9 h 9 m 49.3 s	+ 9.55 s	N. 16° 20' 47.1"	—42.2"	15' 47.7"	5 m 34.3 s	.30 s	9 h 4 m 14.0 s
9	9 13 38.3	9.33	16 3 47.3	42.8	15 47.8	5 26.8	.33	9 8 10.6
10	9 17 26.7	9.50	15 46 32.1	43.4	15 48.0	5 18.7	.35	9 12 7.1

NAUTICAL ALMANAC ELEMENTS FOR SEPTEMBER, 1902

SUB. FROM APP. TIME

Date	Sun's Right Ascension.	Hourly Diff.	Sun's Declination	Hourly Diff.	Semi-Diameter	Equation of Time	Hourly Diff.	Sidereal Time at Green. Mean Noon
21	11 h 51 m 0 9 s	+ 8.97 s	N. 0° 58' 26.3"	—58.3"	15' 57.2"	6 m 40.3 s	.88 s	11 h 57 m 42.3 s
22	11 54 36.3	8.98	0 35 5.8	58.4	15 57.5	7 1.4	.88	12 1 38.9
23	11 58 11.8	8.98	N. 0 11 43.9	58.4	15 57.8	7 22.5	.87	12 5 35.4
24	12 1 47.4	8.99	S. 0 11 39 1	58.5	15 58.0	43.3	.87	12 9 32.0

NAUTICAL ALMANAC ELEMENTS FOR OCTOBER, 1902

Date	Sun's Right Ascension	Hourly Diff.	Sun's Declination	Hourly Diff.	Semi-Diameter	Equation of Time. — from App. Time	Hourly Diff.	Sidereal Time at Green. Mean Noon
3	12 h 34 m 17.0 s	+ 9.07 s	S. 3° 41' 55.2"	—58.1"	16' 00.5"	10 m 42.2 s	.78 s	12 h 45 m 1.0 s
4	12 37 54.9	9.09	4 5 9.1	58.0	16 00.8	11 00.8	.77	12 48 57.5
5	12 41 33.2	9.10	4 28 20.0	57.9	16 1.1	11 19.0	.75	12 52 54.1
15	13 18 17.9	9.28	8 16 7.5	55.7	16 3.8	13 59.3	.57	13 32 19.6
18	13 29 29.0	9.36	9 22 28.4	54.8	16 4.6	14 37.8	.50	13 44 9.2
19	13 33 13.8	9.38	9 44 19.8	54.5	16 4.9	14 49.5	.47	13 48 5.8
20	13 36 59.3	9.41	10 6 2.7	54.1	16 5.2	15 00.5	.44	13 52 2.4
21	13 40 45.5	9.44	10 27 36.7	53.7	16 5.4	15 10.9	.42	13 55 58.9
22	13 44 32.3	9.46	10 49 1.5	53.3	16 5.7	15 20.6	.39	13 59 55.5

NAUTICAL ALMANAC ELEMENTS FOR NOVEMBER, 1902

— FROM APP. TIME

22	15 h 48 m 8.6 s	+10.50 s	S. 19° 59' 53.9"	—32.8"	16' 13.0"	13 m 57.7 s	.64 s	16 h 2 m 8.6 s
23	15 52 21.1	10.54	20 12 50.7	31.9	16 13.2	13 41.9	.68	16 6 5.2
24	15 56 34.4	10.57	20 25 25.2	31.0	16 13.4	13 25.2	.71	16 10 1.8

NAUTICAL ALMANAC ELEMENTS FOR DECEMBER, 1902

— FROM APP. TIME

9	17 h 1 m 17.7 s	+10.97 s	S. 22° 45' 48.2"	—15.4"	16' 15.6"	7 m 51.1 s	1.11 s	17 h 9 m 10.1 s
10	17 5 41.1	10.98	22 51 43.9	14.2	16 15.7	7 24.4	1.12	17 13 6.7
16	17 32 9.3	11.07	23 17 42.8	7.4	16 16.4	4 35.9	1.21	17 36 46.0
17	17 36 35.0	11.08	23 20 25.5	6.2	16 16.5	4 6.8	1.22	17 40 42.6

FOR BEGINNING OF 1902.

Mean Places of Stars Used in This Work.

Name of Star	Magnitude	Right Ascension			Annual Variat'n	Declination			Annual Variation
Algenib	3	0 h	08 m	11.30s	+3.085	+14°	38'	19.5''	+20.02''
a. Arietis ...	2	2	01	38.80	3.373	+22	59	57.1	17.14
Polaris	2	1	23	24.04	25.628	+88	47	04.1	18.74
Aldebaran ..	1	4	30	17.77	3.439	+16	18	45.0	7.46
Canopus ...	1	6	21	46.59	1.332	—52	38	31.4	—1 89
Sirius	1	6	40	49.78	2.644	—16	34	53.6	4.76
Castor	2	7	28	20.89	3.835	+32	06	13.9	7.62
Procyon....	1	7	34	10.34	3.143	+5	28	34.5	9.04
Spica.......	1	13	20	01.74	3.155	—10	38	59.3	18.87
Arcturus ...	1	14	11	11.47	2.735	+19	41	33.0	18.85
Antares	1	16	23	23.82	3.672	—26	12	52.9	8.23
Altair	1	19	46	00.12	2.927	+8	36	33.3	+9.32
Fomalhaut..	1–5	22	52	14.22	3.324	—30	08	30.2	19.00

ANSWERS.

MULTIPLICATION BY LOGARITHMS

1. 729.6, 2. 1201200, 3. 2027, 4, .0144445.

DIVISION BY LOGARITHMS

1. 47, 2. 49.97, 3. 432640, 4. .0161.

PARALLEL SAILING

1. 59.97, 2. 65.92. 3. 51.7, 4. 419.96.

DAYS WORK

1. True Courses—N. 2 pts. W. 6 miles; N. 1 W. 17 m; N. 1½ W. 18; S. 4 W. 22; S. 5½ W. 25; S. 5 W. 26; S. 2½ E. 28; N. 4 W. 28.

Diff. Lat. 7′.3 S. Dep. 76′.7 W.; Lat. in 38° 9′ N.; Diff. Long 97 miles.

Long. in 13° 37′ E.; Course S. 85° W.; distance 77 miles.

2. *True Courses*—S. 89° W. 5; N. 23° W. 29; N. 37° W. 31; N. 46° W. 33; N. 36° W. 32; S. 41° W. 30.; S. 67° W. 29; N. 29° W. 30.

Diff. Lat. 92′.5 N.; Dep. 138′.4 W.; Lat. in 41° 53′ N.; Diff. Long. 184 miles.

Long. in 128° 24′ W.; course N. 56° W.; distance 167 miles.

3. *True Courses*—S. 7 pts. E. 12 m.; N. 4 E. 25; N. 2½ E. 26; N. 1 E. 33; S. 3¾ E. 30; S. 1 E. 26; S. 7½ W. 22; N. 2 E. 24.

Diff. Lat. 43.0 N.; Dep. 60.7 E.; Lat. in 49° 46′ S.; Diff. Long. 94 miles.

Long. in 57° 46′ W.; course N. 55° E.; distance 74 miles.

LATITUDE BY SUN'S MERIDIAN ALTITUDE

1. A. T. Green. 26 d 13 h 57 m 0 s; Corr. Decl. 8° 33′ 21″ S.; True Alt. 50° 15′ 35″; Latitude, 48° 17′ 46″ South.

2. A. T. Green. 17 d 8 h 30 m 40 s; Decl. 20° 42′ 20″ S.; True Alt. 56° 11′ 50″; Latitude, 60° 30′ 24″ South.

3. A. T. Green. 6 d 21 h 36 m; Decl. 16° 31′ 18″ N.; T. Alt. 62° 45′ 48″; Latitude 43° 45′ 30″ North.

4. A. T. Green. 4 d 11 h 55 m 20 s; Decl. 22° 28′ 31″ N.; T. Alt. 69° 29′ 50″; Latitude, 1° 58′ 21″ North.

5. A. T. Green. 12 d 16 h 20 m 4 s; Decl. 7° 35′ 9″ S.; T. Alt. 61° 18′ 24″; Latitude, 21° 06′ 27″ North.

MERCATOR'S SAILING

1. Diff. Lat. 734; Mer. diff. Lat. 1004; Diff. long. 264; Course S. 14° 44′ E.; Dist. 758.9 miles.

2. Diff. Lat. 1392; Mer. diff. Lat. 1403; Diff. long. 1712; Course S. 50° 40′ E.; Dist. 2196 miles.

3. Diff. Lat. 1325; Mer. diff. Lat. 1334; Diff. long. 4358; Course S. 72° 59′ E.; Dist. 4528 miles.

4. Diff. Lat. 607; Mer. diff. Lat. 909; Diff. long. 3793; Course N. 76° 31½′ W.; Dist. 2605 miles.

AMPLITUDES

1. Err. 5° 55′ 30″ W.; Dev. 4° 04′ 30″ E.
2. Err. 10° 29′ 30″ W.; Dev. 20° 34′ 30″ W.
3. Err. 16° 15′ 30″ E.; Dev. 4° 15′ 30″ E.

4. A. T. G. 22 d 19 h 35 m 54 s; Decl. 20° 10′ 14″ N.; T. Amp. W. 32° 3′ N.; Err. 8° 33′ E.; Dev. 3° 27′ W.

5. A. T. G. 5 d 23 h 18 m 50 s; Decl. 15° 55′ 49″ S.; T. Amp. W. 22° 13′ 30″ S.; Err. 5° 21′ W.; Dev. 3° 9′ E.

LONGITUDE BY CHRONOMETER

1. M. T. G. 16 d 19 h 16 m 45 s; Decl. 23° 19′ 56″ S.; Equ. Time,—4 m 13 s ; True Alt. 27° 13′ 08″; Hour Angle 3 h 24 m 42 s; Long. 120° 56′ East.

2. M. T. G. 4 d 7 h 40 m 19 s; Decl. 22° 23′ 44″ N.; Equ. Time,—2 m 1 s; True Alt. 41° 12′ 23″; H. Angle 3 h 23 m 29 s; Long. 166° 27′ 15″ West.

3. M. T. G. 9 d 19 h 2 m 3 s; Decl. 22° 50′ 33″ S.; Equ. Time, —7 m 30 s; True Alt. 12° 39′ 42″; H. Angle 3 h 56 m 19 s; Long. at Sights 131° 41′ 30″ East; Long. at Noon 132° 07′ 30″ East.

4. M. T. G. 11 h 7 h 07 m 37 s; Daily Rate 3.7 s; Decl. 17° 47′ 04″ N.; Equ. Time,—3 m 45 s; True Alt. 10° 33′ 41″; H. Ang. 3 h 54 m 37 s; Long. 166° 29′ 45″ West.

ALTITUDE AZIMUTHS

1. True Azim. N. 51° 54′ W.; Error 9° 43′ W.; Deviation 6° 17′ East.

2. True Azim. N. 46° 02′ E.; Error 12° 17′ E.; Deviation 4° 54′ West.

3. True Azim. S. 84° 51′ W.; Error 8° 29′ W.; Deviation 22° 34′ West.

4. True Azim. S. 86° 2′ E.; Error 9° 36′ E.; Deviation 11° 40′ East.

TIME AZIMUTHS

1. True Azim. S. 103° 4′ W. 2. True Azim. N. 109° 34′ E.

3. True Azim. N. 135° 4′ E. 4. True Azim. S. 134° 19′ W.

REDUCTIONS

1. A. T. G. Jan. 4 d 11 h 4 m 1 s; Decl. 22° 44′ 45″ S.; True Alt. 33° 8′ 51″; Time From Noon 26 m 25 s; Natural Number 510; Latitude, 33° 45′ North.

2. A. T. G. 15 d 19 h 32 m 26 s; Decl. 21° 31′ 12″ N.; True Alt. 42° 49′ 59″; Time From Noon 13 m 54 s; Number 155; Lat. 25° 31′ 48″ South.

3. A. T. G. 6 d 9 h 50 m 42 s; Decl. 22° 43′ 45″ N.; True Alt.

28° 9′; Time From Noon 23 m 46 s; Number 387.1; Latitude 38° 52′ 15″ South.

4. M. T. G. 9 d 6 h 5 m 51 s; Decl 15° 59′ 26″ N.; Equ. Time, —5 m 25 s; True Alt. 43° 51′ 58″; Time From Noon 21 m 58 s; Number 384.0; Latitude, 29° 50′ 13″ South.

STAR LATITUDE

1. True Alt. 53° 53′ 40″; Decl. 14° 38′ 19″ N.; Latitude 50° 44′ 39″ North.

2. True Alt. 52° 41′ 16″; Decl. 26° 12′ 53″ S.; Latitude 63° 31′ 37″ South.

3. True Alt. 64° 13′ 25″; Decl! 32° 6′ 14″ N.; Latitude 6° 19 39″ North.

4. True Alt. 55° 56′ 15″; Decl. 16° 18′ 45″ N.; Latitude 50° 22′ 30″ North.

POLARIS

1. M. T. G. 12 d 18 h 32 m 38 s; Sid. Time at Obs. 14 h 20 m 49 s; Red. Alt. 41° 4′ 09″; Latitude 42° 14′ 12″ North.

2. M. T. G. 21 d 4 h 2 m 4 s; Sid. Time at Obs. 2 h 8 m 21 s; Red. Alt. 29° 55′ 18″; Latitude 28° 44′ 18″ North.

STAR LONGITUDE

1. M. T. G. 8 d 2 h 11 m 15 s; T. Alt. 41° 54′ 39″; P. D. 59° 51′ 30″; Red. Sid. T. 9 h 4 m 36 s; H. Ang. W. 3 h 57 m 31 s; R. A. Mer. 2 h 49 m 45 s; M. T. S. 7 d 17 h 45 m 9 s; Longitude 126° 31′ 30″ West.

2. M. T. G. 28 d 21 h 26 m 45 s; T. Alt. 22° 14′ 20″; P. D. 106° 34′ 54″; Red. Sid. T. 20 h 30 m 47 s; H. Ang. E. 1 h 1 m 38 s; R. A. Mer. 5 h 39 m 12 s; M. T. S. 29 d 9 h 8 m 25 s; Longitude 175° 25′ 00″ East.

SUMNER

1. Line of Bearing at time of first Obs. N. 56° E. Suns True Bearing S. 34° E. Ship's pos. at time of second Obs. Lat. 50° 27′ N.; Long. 9° 23′ W.

2. Line of Bearing at time of first Obs. N. 64° W.; Sun's True Bearing S. 26° W.; Ship's pos. at time of second Obs. Latitude 49° 43′ N.; Long. 170° 28′ W.

JOHNSON'S METHOD

1. Corr. for second Lat. 3.1′; Corr. for Long. 1 5.2′; Corr. for

Long. [2] 13.2′; Latitude 46° 46′ 18″ N.; Longitude 163° 20′ 33″ E.

STAR AZIMUTH

1. A. T. G. 19 d 9 h 34 m 16 s; Red. Sun's R. A. 13h 34 m 42 s; R. A. Mer. 5 h 36 m 42 s; Hour Ang. E. 1 h 4 m 8 s; True Azim. N. 24° E.; Comp. Err. 27° 40′ E.; Deviation 17° 50′ East.

2. M. T. S. 18 d 8 h 30 m 10 s; Red. Sid. Time 19 h 49 m 0 s; R. A. Mer. 4 h 19 m 10 s; H. Ang. W. 2 h 17 m 31 s; T. Azim. N. 33° 30′ W.; Comp. Err. 2° 0′ E. Deviation 11° 10′ West.

THE BEAUFORT NOTATION.

INDICATING THE FORCE OF THE WIND

0. Denotes calm.
1. Light air: just sufficient to give steerage way.
2. Light breeze.
3. Gentle breeze.
4. Moderate breeze.
5. Fresh breeze.
6. Strong breeze.
7. Moderate gale.
8. Fresh gale.
9. Strong gale.
10. Whole gale.
11. Storm.
12. Hurricane

INDICATING THE WEATHER

b. Blue sky.
c. Clouds (detached.)
d. Drizzling rain
f. Foggy.
g. Gloomy.
h. Hail.
l. Lightning.
m. Misty.
o. Overcast.
p. Passing showers.
q. Squally.
r. Rain.
s. Snow.
t. Thunder.
u. Ugly (threatening).
v. Visibility { remarkable vis. of distant objects
w. Wet (dew).

A bar (—) under any letter augments its signification; thus $\underline{\text{f.}}$ very foggy; $\underline{\text{r.}}$ heavy rain, etc.

Note:—The above has been added owing to the request of brother Navigators.

PILOT RULES

— FOR —

ATLANTIC AND PACIFIC COAST INLAND WATERS.

Rules and Regulations for the government of pilots of vessels propelled by steam, gas, fluid, naphtha, or electric motors, or of other vessels propelled by machinery, navigating the harbors, rivers, and inland waters of the United States (except the Great Lakes and their connecting and tributary waters as far east as Montreal, the Red River of the North, and rivers emptying into the Gulf of Mexico, and their tributaries). Adopted by the Board of Supervising Inspectors of Steam Vessels January 26, 1899, under the authority of an act of Congress approved June 7, 1897.

In the following rules the words "steam vessel" and "steamer" shall include any vessel propelled by machinery.

REGULATIONS FOR PREVENTING COLLISIONS AT SEA.

PRELIMINARY.

In the following rules every steam vessel which is under sail and not under steam is to be considered a sailing vessel, and every vessel under steam, whether under sail or not, is to be considered a steam vessel.

The word "steam-vessel" shall include any vessel propelled by machinery.

A vessel is "under way," within the meaning of these rules, when she is not at anchor, or made fast to the shore, or aground.

RULES CONCERNING LIGHTS, ETC.

1. The word "visible" in these rules, when applied to lights,

shall mean visible on a dark night with a clear atmosphere.

ARTICLE 1. The rules concerning lights shall be complied with in all weathers from sunset to sunrise, and during such time no other lights which may be mistaken for the prescribed lights shall be exhibited.

Art. 2. A steam vessel when under way shall carry:

(a) On or in front of the foremast, or, if a vessel without a foremast, then in the fore part of the vessel, a bright white light so constructed as to show an unbroken light over an arc of the horizon of twenty points of the compass, so fixed as to throw the light ten points on each side of the vessel, namely, from right ahead to two points abaft the beam on either side, and of such a character as to be visible at a distance of at least five miles.

(b) On the starboard side a green light so constructed as to show an unbroken light over an arc of the horizon of ten points of the compass, so fixed as to throw the light from right ahead to two points abaft the beam on the starboard side, and of such a character as to be visible at a distance of at least two miles.

(c) On the port side a red light so constructed as to show an unbroken light over an arc of the horizon of ten points of the compass, so fixed as to throw the light from right ahead to two points abaft the beam on the port side, and of such a character as to be visible at a distance of at least two miles.

(d) The said green and red side-lights shall be fitted with inboard screens projecting at least three feet forward from the light so as to prevent these lights from being seen across the bow.

(e) A sea-going steam vessel when under way may carry an additional white light similar in construction to the light mentioned in subdivision (a). These two lights shall be so placed in line with the keel that one shall be at least fifteen feet higher than the other, and in such a position with reference to each other that the lower light shall be forward of the upper one. The vertical distance between these lights shall be less than the horizontal distance.

Art. 3. A steam-vessel when towing another vessel, shall, in addition to her side lights, carry two bright white lights in a vertical line one over the other, not less than three feet apart, and when towing more than one vessel shall carry an additional bright white light three feet above or below such lights, if the length of the tow, measuring from the stern of the towing vessel to the stern of the last vessel towed, exceeds six hundred feet. Each of these lights shall be of the same construction and character, and shall be carried in the same position as the white light mentioned in article two (a).

Such steam vessel may carry a small white light abaft the funnel or aftermast for the vessel towed to steer by, but such light shall not be visible forward of the beam.

Art. 5. A sailing vessel under way or being towed shall carry the same lights as are prescribed by article two for a steam-vessel under way, with the exception of the white lights mentioned therein, which they shall never carry.

Art. 6. Whenever, as in the case of vessels of less than ten gross tons under way during bad weather, the green and red side-lights can not be fixed, these lights shall be kept at hand, lighted and ready for use; and shall, on the approach of or to other vessels, be exhibited on their respective sides in sufficient time to prevent collision, in such manner as to make them most visible, and so that the green light shall not be seen on the port side, nor the red light on the starboard side, nor, if practicable, more than two points abaft the beam on their respective sides. To make the use of these portable lights more certain and easy the lanterns containing them shall each be painted outside with the color of the light they respectively contain, and shall be provided with proper screens.

Art. 7. Rowing boats, whether under oars or sail, shall have ready at hand a lantern showing a white light which shall be temporarily exhibited in sufficient time to prevent collision.

Art. 8. Pilot vessels when engaged on their station on pilotage duty shall not show the lights required for other vessels, but shall carry a white light at the masthead, visible all around the horizon, and shall also exhibit a flare-up light or flare-up

lights at short intervals, which shall never exceed fifteen minutes.

On the near approach of or to other vessels they shall have their side lights lighted, ready for use, and shall flash or show them at short intervals, to indicate the direction in which they are heading, but the green light shall not be shown on the port side nor the red light on the starboard side.

A pilot-vessel of such a class as to be obliged to go alongside of a vessel to put a pilot on board may show the white light instead of carrying it at the masthead, and may, instead of the colored lights above mentioned, have at hand, ready for use, a lantern with a green glass on the one side and a red glass on the other, to be used as prescribed above.

Pilot-vessels, when not engaged on their station on pilotage duty, shall carry lights similar to those of other vessels of their tonnage.

Art. 9. (a) Fishing vessels of less than ten gross tons, when under way and when not having their nets, trawls, dredges, or lines in the water, shall not be obliged to carry the colored side lights; but every such vessel shall, in lieu thereof, have ready at hand a lantern with a green glass on one side and a red glass on the other side, and on approaching to or being approached by another vessel such lantern shall be exhibited in sufficient time to prevent collision, so that the green light shall not be seen on the port side nor the red light on the starboard side.

(b) All fishing vessels and fishing boats of ten gross tons or upward, when under way and when not having their nets, trawls, dredges, or lines in the water, shall carry and show the same lights as other vessels under way.

(c) All vessels, when trawling, dredging, or fishing with any kind of drag-nets or lines, shall exhibit, from some part of the vessel where they can be best seen, two lights. One of these lights shall be red and the other shall be white. The red light shall be above the white light, and shall be at a vertical distance from it of not less than six feet and not more than twelve feet; and the horizontal distance between them, if any, shall not be

more than ten feet. These two lights shall be of such a character and contained in lanterns of such construction as to be visible all around the horizon, the white light a distance of not less than three miles and the red light of not less than two miles.

Art. 10. A vessel which is being overtaken by another, except a steam-vessel with an after range-light showing all around the horizon, shall show from her stern to such last-mentioned vessel a white light or a flare-up light.

Art. 11. A vessel under one hundred and fifty feet in length when at anchor shall carry forward, where it can best be seen, but at a height not exceeding twenty feet above the hull, a white light, in a lantern so constructed as to show a clear, uniform, and unbroken light visible all around the horizon at a distance of at least one mile.

A vessel of one hundred and fifty feet or upwards in length when at anchor shall carry in the forward part of the vessel, at a height of not less than twenty and not exceeding forty feet above the hull, one such light, and at or near the stern of the vessel, and at such a height that it shall be not less than fifteen feet lower than the forward light, another such light.

The length of a vessel shall be deemed to be the length appearing in her certificate of registry.

Art. 12. Every vessel may, if necessary, in order to attract attention, in addition to the lights which she is by these rules required to carry, show a flare-up light or use any detonating signal that can not be mistaken for a distress signal.

Art. 13. Nothing in these rules shall interfere with the operation of any special rules made by the government of any nation with respect to additional station and signal lights for two or more ships of war or for vessels sailing under convoy, or with the exhibition of recognition signals adopted by shipowners, which have been authorized by their respective governments, and duly registered and published.

Art. 14. A steam-vessel proceeding under sail only, but having her funnel up, may carry in daytime, forward, where it can best be seen, one black ball or shape two feet in diameter.

SOUND SIGNALS FOR FOG, ETC.

Art. 15. All signals prescribed by this article for vessels under way shall be given:

1. By "steam-vessels" on the whistle or siren.

2. By "sailing-vessels" and "vessels towed" on the fog horn.

The words "prolonged blast" used in this article shall mean a blast of from four to six seconds duration.

A steam vessel shall be provided with an efficient whistle or siren, sounded by steam or by some substitute for steam, so placed that the sound may not be intercepted by any obstruction, and with an efficient fog horn; also with an efficient bell. A sailing vessel of twenty tons gross tonnage or upward shall be provided with a similar fog horn and bell.

In fog, mist, falling snow, or heavy rainstorms, whether by day or night, the signals described in this article shall be used as follows, namely:

(a) A steam-vessel under way shall sound, at intervals of not more than one minute, a prolonged blast.

(c) A sailing vessel under way shall sound, at intervals of not more than one minute, when on the starboard tack, one blast; when on the port tack, two blasts in succession, and when with the wind abaft the beam, three blasts in succession.

(d) A vessel when at anchor shall, at intervals of not more than one minute, ring the bell rapidly for about five seconds.

(e) A steam-vessel when towing, shall, instead of the signals prescribed in subdivision (a) of this article, at intervals of not more than one minute, sound three blasts in succession, namely, one prolonged blast followed by two short blasts. A vessel towed may give this signal and she shall not give any other.

SPEED OF SHIPS TO BE MODERATE IN FOG, ETC.

Art. 16. Every vessel shall, in a fog, mist, or falling snow, or heavy rainstorms, go at a moderate speed, having careful regard to the existing circumstances and conditions.

A steam-vessel hearing, apparently forward of her beam, the fog signal of a vessel the position of which is not ascertained shall, so far as the circumstances of the case admit, stop her engines, and then navigate with caution until danger of collision is over.

STEERING AND SAILING RULES—PRELIMINARY—

RISK OF COLLISION.

Risk of collision can, when circumstances permit, be ascertained by carefully watching the compass bearing of an approaching vessel. If the bearing does not appreciably change, such risk should be deemed to exist.

Art. 17. When two sailing vessels are approaching one another, so as to involve risk of collision, one of them shall keep out of the way of the other as follows, namely:

(a) A vessel which is running free shall keep out of the way of a vessel which is close-hauled.

(b) A vessel which is close-hauled on the port tack shall keep out of the way of a vessel which is close-hauled on the starboard tack.

(c) When both are running free, with the wind on different sides, the vessel which has the wind on the port side shall keep out of the way of the other.

(d) When both are running free, with the wind on the same side, the vessel which is to the windward shall keep out of the way of the vessel which is to the leeward.

(e) A vessel which has the wind aft shall keep out of the way of the other vessel.

Art. 18. Rule 1. When steam-vessels are approaching each other head and head, that is, end on, or nearly so, it shall be the duty of each to pass on the port side of the other; and either vessel shall give, as a signal of her intention, one short and distinct blast of her whistle, which the other vessel shall answer promptly by a similar blast of her whistle, and thereupon such vessels shall pass on the port side of each other. But if the courses of such vessels are so far on the starboard of each other as not to be considered as meeting head and head, either

vessel shall immediately give two short and distinct blasts of her whistle, which the other vessel shall answer promptly by two similiar blasts of her whistle, and they shall pass on the starboard side of each other.

The foregoing only applies to cases where vessels are meeting end on or nearly end on, in such a manner as to involve risk of collision; in other words, to cases in which, by day, each vessel sees the masts of the other in a line, or nearly in a line, with her own, and by night to cases in which each vessel is in such a position as to see both the side-lights of the other.

It does not apply by day to cases in which a vessel sees another ahead crossing her own course, or by night to cases where the red light of one vessel is opposed to the red light of the other, or where the green light of one vessel is opposed to the green light of the other, or where a red light without a green light or a green light without a red light, is seen ahead, or where both green and red lights are seen anywhere but ahead.

Rule II. When steamers are approaching each other in an oblique direction, so as to involve risk of collision, the vessel which has the other on her own starboard side shall keep out of the way of the other, which latter vessel shall keep her course and speed; the steam-vessel having the other on her starboard side indicating by one blast of her whistle her intention to direct her course to starboard, so as to cross the stern of the other steamer; and two blasts her intention of directing her course to port. which signals must be promptly answered by the steamer having the right of way, but the giving and answering signals by a vessel required to keep her course shall not vary the duties and obligations of the respective vessels.

Rule III. If, when steam-vessels are approaching each other, either vessel fails to understand the course or intention of the other, from any cause, the vessel so in doubt shall immediately signify the same by giving several short and rapid blasts, not less than four, of the steam whistle.

Rule IV When steamers are running in a fog, mist, falling snow, or heavy rainstorms, except when towing, it shall be

the duty of the pilot to cause a long blast of the whistle to be sounded at intervals not exceeding one minute.

A steam-vessel when towing shall, at intervals of not more than one minute, sound three blasts in succession, namely, one prolonged blast, followed by two short blasts. A vessel towed may give this signal, and she shall not give any other.

A vessel is "under way" within the meaning of these rules, when she is not at anchor, or made fast to the shore, or aground.

Every steam-vessel shall, in a fog, mist, falling snow, or heavy rainstorms, go at a moderate speed, having careful regard to the existing circumstances and conditions.

A steam-vessel hearing, apparently forward of her beam, the fog signal of a vessel the position of which is not ascertained shall, so far as the circumstances of the case admit, stop her engines, and then navigate with caution until danger of collision is over.

Rule V. Whenever a steam-vessel is nearing a short bend or curve in the channel, where, from the height of the banks or other cause, a steam-vessel approaching from the opposite direction can not be seen for a distance of half a mile, such steam-vessel, when she shall have arrived within half a mile of such curve or bend, shall give a signal by one long blast of the steam whistle, which signal shall be answered by a similar blast, given by any approaching steam-vessel that may be within hearing. Should such signal be so answered by a steam-vessel upon the farther side of such bend, then the usual signals for meeting and passing shall immediately be given and answered; but, if the first alarm signal of such vessel be not answered, she is to consider the channel clear and govern herself accordingly.

When steam-vessels are moved from their docks or berths, and other boats are liable to pass from any direction toward them, they shall give the same signal as in the case of vessels meeting at a bend, but immediately after clearing the berths so as to be fully in sight they shall be governed by the steering and sailing rules.

Rule VIII. When steam-vessels are running in the same direction, and the vessel which is astern shall desire to pass on

the right or starboard hand of the vessel ahead, she shall give one short blast of the steam whistle, as a signal of such desire, and if the vessel ahead answers with one blast, she shall put her helm to port; or if she shall desire to pass on the left or port side of the vessel ahead, she shall give two short blasts of the steam whistle as a signal of such desire, and if the vessel ahead answers with two blasts, shall put her helm to starboard; or if the vessel ahead does not think it safe for the vessel astern to attempt to pass at that point, she shall immediately signify the same by giving several short and rapid blasts of the steam whistle, not less than four, and under no circumstances shall the vessel astern attempt to pass the vessel ahead until such time as they have reached a point where it can be safely done, when said vessel ahead shall signify her willingness by blowing the proper signals. The vessel ahead shall in no case attempt to cross the bow or crowd upon the course of the passing vessel.

Rule IX. The whistle signals provided in the rules under this article, for steam-vessels meeting, passing, or overtaking, are never to be used except when steamers are in sight of each other, and the course and position of each can be determined in the daytime by a sight of the vessel itself, or by night by seeing its signal lights. In fog, mist, falling snow, or heavy rain-storms, when vessels can not so see each other, fog signals only must be given.

Art. 19. When two steam-vessels are crossing, so as to involve risk of collision, the vessel which has the other on her own starboard side shall keep out of the way of the other.

Art. 20. When a steam-vessel and a sailing vessel are proceeding in such directions as to involve risk of collision, the steam-vessel shall keep out of the way of the sailing vessel.

Art. 21. Where, by any of these rules, one of the two vessels is to keep out of the way, the other shall keep her course and speed.

Art. 22. Every vessel which is directed by these rules to keep out of the way of another vessel shall, if the circumstances of the case admit, avoid crossing ahead of the other.

Art. 23. Every steam-vessel which is directed by these

rules to keep out of the way of another vessel shall, on approaching her, if necessary, slacken her speed or stop or reverse.

Art. 24. Notwithstanding anything contained in these rules every vessel, overtaking any other, shall keep out of the way of the overtaken vessel.

Every vessel coming up with another vessel from any direction more than two points abaft her beam, that is, in such a position with reference to the vessel which she is overtaking that at night she would be unable to see either of that vessel's side lights, shall be deemed to be an overtaking vessel; and no subsequent alteration of the bearing between the two vessels shall make the overtaking vessel a crossing vessel within the meaning of these rules, or relieve her of the duty of keeping clear of the overtaking vessel until she is finally past and clear.

As by day the overtaking vessel can not always know with certainty whether she is forward of or abaft this direction from the other vessel she should, if in doubt, assume that she is an overtaking vessel and keep out of the way.

Art. 25. In narrow channels every steam-vessel shall, when it is safe and practicable, keep to that side of the fairway or mid-channel which lies on the starboard side of such vessel.

Art. 26. Sailing vessels under way shall keep out of the way of sailing vessels or boats fishing with nets, or lines, or trawls. This rule shall not give to any vessel or boat engaged in fishing the right of obstructing a fairway used by vessels other than fishing vessels or boats.

Art. 27. In obeying and construing these rules due regard shall be had to all dangers of navigation and collision, and to any special circumstances which may render a departure from the above rules necessary in order to avoid immediate danger.

SOUND SIGNALS FOR VESSELS IN SIGHT OF ONE ANOTHER.

Art. 28. When vessels are in sight of one another a steam vessel under way whose engines are going at full speed

astern shall indicate that fact by three short blasts on the whistle.

NO VESSEL UNDER ANY CIRCUMSTANCES TO NEGLECT PROPER PRECAUTIONS.

Art. 29. Nothing in these rules shall exonerate any vessel, or the owner or master or crew thereof, from the consequences of any neglect to carry lights or signals, or of any neglect to keep a proper lookout, or of the neglect of any precaution which may be required by the ordinary practice of seamen, or by the special circumstances of the case.

Art. 30. The exhibition of any light on board of a vessel of war of the United States or a revenue cutter may be suspended whenever, in the opinion of the Secretary of the Navy, the commander in chief of a squadron, or the commander of a vessel acting singly, the special character of the service may require it.

AIDS TO MEMORY IN VERSE

By Thomas Gray.

1. *Two Steamships Meeting:*

   When both side lights I see ahead,
   I port my helm and show my *red.*

2. *Two Steamships Passing:*

   Green to *green,* or *red* to *red*—
   Perfect safety—go ahead!

3. *Two Steamships Crossing:*

Note.—This is the position of greatest danger; there is nothing for it but good lookout, caution and judgment.

If to my starboard *red* appear,
It is my duty to keep clear;

To act as judgment says is proper—
To port, or starboard, back, or stop her!
But when upon my port is seen
A steamer's starboard light of *green,*
For me there's nought to do but see
That *green* to port keeps clear of me.

4. *All Ships Must Keep a Good Lookout, and Steamships Must Stop and Go Astern, if Necessary.*

Both in safety and in doubt
I always keep a good lookout;
In danger, with no room to turn,
I ease her! Stop her! Go astern!

DISTRESS SIGNALS.

Art. 31. When a vessel is in distress and requires the assistance from other vessels or from the shore the following shall be the signals to be used or displayed by her, either together or separately, namely:

IN THE DAYTIME.

A continuous sounding with any fog signal apparatus, or firing a gun.

AT NIGHT.

First. Flames on the vessel as from a burning tar barrel, oil barrel, and so forth.

Second. A continuous sounding with any fog signal apparatus, or firing a gun.

LATITUDE BY MERIDIAN ALTITUDE OF THE MOON.

Usually, when conditions are favorable for observing altitudes of the moon to obtain ship's position at sea, star observations can be had to better advantage, giving better results. Because of this fact, the former has not thus far been given space in the Self-Instructor, although the writer has often felt much obliged to the moon for the light she has thrown on the horizon while he has been observing stars.

To comply, however, with the desire of some patrons of the work, this second issue contains, with other additions, latitude by meridian altitude of the moon; for occasions do arise at sea, when the longed-for latitude can be determined by a snap shot of "Fair Luna."

RULES.

1. Take out from page 4 for the month in the Nautical Almanac, the moon's upper meridian passage, or upper transit, for the astronomical day at the head of the question. This will mean the day before, if A. M., or same day, if P. M. Take this element out also for the day before, if east longitude, or day after, if in west longitude.

NOTE.—If the Nautical Almanac gives no meridian passage, or transit, the sun will then be in conjunction with the moon.

2. Subtract the least meridian passage from the greatest and call the remainder retardation. Multiply this by the longitude in time and divide by 24 and we have the correction for the meridian passage of the astronomical day, to be added, if the longitude is west, or subtracted if the longitude is east. The result is the ship mean time of meridian passage, and must be dated for the previous day, if A. M., or same day, if P. M. question. To the ship mean time of meridian passage add the longitude in time, if west, or subtract, if east, and we have mean time at Greenwich.

3. Now correct the moon's declination, semi-diameter and horizontal parallax, as follows.

THE DECLINATION.

4. From Nautical Almanac, pages 5 to 12, for the month take out the declination for the day and hour of mean time at Greenwich, also the difference for 1 minute; multiply this difference by the minutes and tenths of a minute in the Greenwich time, and we have the correction for the declination, to be added if increasing, or subtracted if decreasing.

Example:

EXAMPLE, 1902, Feb. 25th. .9h 01m 30s M. T. G.; what is the moon's declination? 1. 5

Supposed decl. on 25d 9h=	7° 57' 08" .9 S	Diff. in 1 min.
Decl. incr. = Corr.	+ 14. 4	9".582
Corr. decl.	7 .57 .23 .3 S	1.5
		47910
		9582
		14.3730

NOTE.—The approximate latitude used for correcting the horizontal parallax is found by subtracting the altitude from 90°, and applying the declination to nearest degree.

SEMI-DIAMETER AND HORIZONTAL PARALLAX.

5. From Nautical Almanac, page 4 of the month, take out the semi-diameter and horizontal parallax for both noon and midnight of the Greenwich time (when the Greenwich hours exceed 12, take out for midnight same day, and for noon of next day), the difference in each case is the change in 12 hours, which multiplied by the remaining hours and tenths of an hour of the Greenwich time, and divided by 12, gives the correction to be added to the semi-diameter, and horizontal parallax as taken from the almanac, if increasing; but subtracted if decreasing. We now have the reduced semi-diameter and horizontal parallax.

6. From Table 18, Bowditch, or Table D, Norie, take out the augmentation, which add to the reduced semi-diameter, and we have the correct semi-diameter.

7. From Table 19, Bowditch, or Table E, Norie, take out the correction for latitude, which subtract from the reduced horizontal parallax.

EXAMPLE.—1902, March 17th 4 h 17 m 36 s M. T. G.; Lat. 39° N., Alt. 52° 31′. Required, the moon's semi-diameter and horizontal parallax.

M. T. G. Mar. 17d 4h 17m 36s
4 .3

S. dia. 17th, noon....	16' 04'' .4	H. Par. 17th, noon....	58' 53'' .4
S. dia. 17th, midnight	16 .01 .4	H. Par. 17th, midnight	58 42 .6
	3		.10 .8
	4.3		.4 .3
	12) 12.9		324
Corr. —	1.75		432
S. dia. noon......	16 .4 .4		12) 46 44
Red. S. dia.......	16 2 .7	Corr. —	3 .87
Aug.....	+ 13 .1	H. Par. Noon....	58 .53.4
Aug. Sem. dia....	16' 16''	Red. H. Par.....	58 .49 .5
		Lat. 39° N.	— 4 .5
		Corr. Har. Par.......	58' 45''

8. Correct the observed altitude for index error if any, subtract the dip, add the augmented semi-diameter for a lower limb observation, subtract for an upper limb; apply the correction from Table 24 Bowditch or Table 30 Norie (always add) and the result is the true altitude.

9. Subtract the true altitude from 90° to get the zenith distance. Apply the corrected declination as in sun's meridian altitude question, and the result is the latitude.

FULL EXAMPLE.

1902, February 26th, A. M. at ship; Long. 121° 03′ E.; observed meridian altitude of moon's upper limb was 49° 04′ 30″ bearing south, index error – 30″, eye 28 feet. Find the latitude.

Moon's Upper Transit		Long. E.		
or Mer. Pass. 25th	14h 48m .3	121° 03'	Retard.	45m .4
or Mer. Pass. 24	14 02 .9	4	Long. time	8 .1
Retardation....	45 .4	6,0) 48,4 12		454
		8 04 12		3632
		.2	24	(4) 367 .74
				(6) 91 .93
			Corr....	15 .32

Mer. Pass........	25th 14h 48m .3	Alt............	49° S.
Corr. —	15 .3		90
Mer. Pass. Ship	25 14 33	Z. D........	41 N.
Long. E	— 8 04 .2	Decl........	7 S.
Mean Time Green	25 6 28 .8	Approx. Lat.	34° N.
	6 .5		

Decl. 25d 6h =	7° 28' 12" .1 S. incr.	
Corr.	+ 4 40	
Red. Decl.	7 .32 .52	

Var. in 1 Min.	
	9" .71
	28 .8
	7768
	7768
	1942
	6,0)27,9 648
Corr.	4.40

Sem. dia. 25th, noon.....	15' 12" .2	Hor. Par. noon......	55' 42" .0
Sem. dia. 25th, midnight.	15 7 .6	Hor. Par. midnight..	55 24 .9
	4 .6		17 .1
	6 .5		6 .5
	230		85 5
	276		1026
	12) 29.90		12) 111 .15
	— 2.49		— 9.26
Sem. dia. noon.....	15 12.2	Hor. Par. noon......	55 42 .00
Red. S. dia........	15 9.71	Red. Hor. Par.......	55 32 .74
Aug...........	+ 11.4	Aug.............	— 3 .4
Corr. S. dia.......	15 21.11	Corr. Hor. Par.......	55 .29 .34

Obs. Alt. U. L.............	49°	04'	30"	S.
Index Err.............	—		30	
	49	04	00	
Dip...................	—	5	11	
	48	58	49	
Aug. S. dia...............	—	15	21	
	48	43	28	
Corr..................	+	35	47	
True Alt.......	49	19	15	
	90	0	0	
Zen. dist..............	40	40	45	N.
Red. decl.................	7	32	52	S.
Latitude..............	33	07	53	North.

LONGITUDE FROM EQUAL ALTITUDES AT SEA.

When the sun's meridian altitude is over 70°, the longitude may be found at the same time as the latitude, with sufficient accuracy for the ordinary purposes of navigation, by observing the times at equal altitudes of the sun, about five or six minutes before and after noon. The sum of these times divided by two and corrected by the equation of time, applied as to mean time, will give the time of mean noon at ship as shown by the watch. Applying to this time the error of the

watch on Greenwich will give Greenwich time at the mean noon of the ship, which is the longitude in time.

EXAMPLE.—September 15th, 1902, latitude by account 7° 02′ N., Long. 125° 10′ W., the following times at equal altitudes of the sun near noon were observed to determine the longitude:

A. M., Watch,	0h	46m	10s
P. M., "	0	57	20
2)	1	43	30
	0	51	45
Equ. of time applied as to mean time	+	4	33
Watch time of ship mean noon	0	56	18
Watch slow on Greenwich	7	24	38
Greenwich time at ship mean noon	8h	20m	56s = Long. 125° 14′ W.

The sun being most probably the only object employed in this way, the equation of equal altitudes, if required, may be computed and applied precisely as if the ship had been stationary; but as the greatest change in the sun's declination in one hour is about one minute, and the change of latitude is generally much greater, the equation of equal altitudes is commonly neglected as relatively unimportant in a method which at sea is necessarily but approximate.

Or, in other words, in latitudes where the sun's meridian altitude is not less than 70°, observe the altitude of the sun about five or six minutes before apparent noon, noting the time by chronometer. After having observed the meridian altitude for latitude (which has nothing to do with the equal altitude problem), set the sextant again to the same altitude you had on before noon, look at the horizon towards the sun, watch carefully for the moment when his limb will appear to touch, and again note the time by the same chronometer. To the mean of the two chronometer times apply the error to date, and we have mean time at Greenwich. Apply the equation of time as to mean time to obtain apparent time at Greenwich. It must now be plain that as midway between the two observations was apparent noon, the apparent time at Greenwich, converted into longitude, must be the longitude of the ship. Greenwich time best, longitude west; Greenwich time least, longitude east.

EXAMPLE—SEPT. 15, 1902.

Chron. time at A. M. obs.,	9h 17m 12s
" " P. M. "	9 . 29 . 10
	2) 18 . 46 . 22
Mean of chron. times,	9 . 23 . 11
Chron. error slow,	+ 3 27
Mean time Green.,	9 . 26 . 38
Equ. of time,	+ 4 . 33
App. time Green.,	9 . 31 . 11 =

= Longitude, 142° 47' 45" West.

REMARKS ON TAKING OBSERVATIONS AT SEA.

Terrestrial Refraction.—The apparent elevations of the summits of high land are subject to great variations, depending upon the particular states of the air.

The apparent place of the sea horizon differs also with different temperatures of the sea and air. When the sea is warmer than the air, the horizon appears below its mean place as that at which it is seen when the air and water are at the same temperature, and the dip taken from the tables is too small; when the sea is colder than the air, the horizon appears above its mean place, and then the tabular dip is too great. These facts being well known, where great accuracy is required the following precautions should be taken:

When the altitude of a heavenly body is above 60°, the altitude may be observed with the sextant from the opposite point of the horizon, as well as from the horizon directly under it. Half the difference of the two readings is the apparent zenith distance of the center. By this means the dip and its uncertainties, together with the index error, are removed. When both the altitude and its supplement are thus measured, and the altitude (the object not being on the meridian) is in a state of change, the time must be noted at each observation; and the resulting zenith distance will correspond to the mean of the times.

When fog obscures the horizon from the deck, a new horizon may often be obtained by taking up a position on the ship as low as possible, or in a small boat.

When the sun's limbs are indistinct, altitudes of the center may be obtained by bisecting the hazy disc upon the horizon.

Height of Waves.—The running of large waves causes the horizon to be in continual motion; while the rise and fall of the observer, both from the lifting of the ship by the waves and her rolling, cause the dip to be continually changing. For this reason a mean of three or five sights should always be taken in rough weather, or in a small vessel. If the altitude be observed above the deck, as in the top, for instance, or from a high bridge, the horizon will appear better defined, and the variations of the dip caused by the ship's motion will be less sensible; also the difference of the temperature of the sea and the air appears to affect the place of the sea horizon less as the observer is more elevated.

From numerous observations made upon the heights, distances, and velocities of waves, the heights are found to vary from 14 to 32 feet. Sir James Ross observed waves of 36 feet in height. The distance from crest to crest of such waves is from 150 to 340 feet, while their velocity appears to vary between 17 and 28 nautical miles per hour.

FINDING THE DISTANCE FROM AN OBJECT BY TWO BEARINGS AND DISTANCE RUN BETWEEN.

Right under the number of points between the ship's course and second bearing and abreast of the difference in points between the course and first bearing is found a number, multiply this by the miles made in the interval, and we have the distance from the object in miles at time of second bearing. Allowance should be made for current, if any.

(See table on next page.)

Difference between Course and first Bearing.	Difference between Ship's Course and second Bearing, in points.																	
Pts	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	10½	11	11½	12	12½
2	1.00	0.81	0.69	0.60	0.54	0.49	0.46	0.43	0.41	0.40	0.39	0.38	0.38	0.38	0.39	0.40	0.41	0.43
2½		1.23	1.00	0.35	0.74	0.67	0.61	0.57	0.53	0.51	0.49	0.48	0.47	0.47	0.47	0.48	0.49	0.51
3			1.45	1.17	1.00	0.88	0.79	0.72	0.67	0.63	0.60	0.58	0.57	0.56	0.56	0.56	0.57	0.58
3½				1.66	1.35	1.14	1.00	0.90	0.82	0.76	0.72	0.69	0.66	0.65	0.64	0.64	0.64	0.65
4					1.85	1.50	1.27	1.11	1.00	0.92	0.85	0.80	0.76	0.74	0.72	0.71	0.71	0.71
4½						2.02	1.64	1.39	1.22	1.09	1.00	0.93	0.88	0.84	0.81	0.79	0.78	0.78
5							2.17	1.77	1.50	1.31	1.18	1.08	1.00	0.94	0.90	0.87	0.85	0.83
5½								2.30	1.87	1.58	1.39	1.25	1.14	1.06	1.00	0.95	0.92	0.90
6									2.41	1.96	1.66	1.46	1.31	1.19	1.11	1.05	1.00	0.97
6½										2.50	2.03	1.72	1.51	1.35	1.24	1.15	1.08	1.03
7											2.56	2.08	1.76	1.55	1.39	1.27	1.18	1.11
7½												2.60	2.11	1.79	1.57	1.41	1.29	1.20
8													2.61	2.12	1.80	1.58	1.41	1.29
8½														2.60	2.11	1.79	1.57	1.41
9															2.56	2.08	1.76	1.55
9½																2.50	2.03	1.72
10																	2.41	1.96
10½																		2.30

EXAMPLE.—Cape Blanco bore N.×E.½ E., ship steered N.N.W. 7 miles, and the cape then bore N.E.½ E. Find the distance from the cape at time of second bearing. The number of points between the course N.N.W. and second bearing, N.E.½ E. is 6½, between N.N.W. and N.×E.½ E. is 3½. Under 6½ and opposite 3½ in the table will be found 1.14. This multiplied by 7 miles, the distance run, will give 7.98 miles, or 8 miles nearly, which is the distance from Cape Blanco when the second bearing was taken.

DISTANCE TABLE.

Giving the distance at which an object can be seen at sea, the height of the object being known, and the height of the observer's eye.

Enter the table with the height of the eye in feet and take out the corresponding distance. Seek also for the distance corresponding to the height of the object in feet. The sum of these distances will equal the distance between the observer and the object.

Height in feet.	Distances. Nautical Miles.	Distances. Land Miles.	Height in feet.	Distances. Nautical Miles.	Distances. Land Miles.	Height in feet.	Distances. Nautical Miles.	Distances. Land Miles.
5	2.56	2.96	70	9.60	11.07	250	18.14	20.92
10	3.63	4.18	75	9.93	11.46	300	19.87	22.91
15	4.44	5.12	80	10.26	11.83	350	21.46	24.75
20	5.13	5.92	85	10.57	12.20	400	22.94	26.46
25	5.74	6.61	90	10.88	12.55	450	24.33	28.06
30	6 28	7 24	95	11.18	12.89	500	25 65	29.58
35	6.79	7.83	100	11.47	13.23	550	26.90	31.02
40	7.25	8.37	110	12.03	13.87	600	28.10	32.40
45	7.70	8.87	120	12.56	14.49	650	29.25	33.73
50	8.11	9.35	130	13.08	15.08	700	30.28	35.00
55	8.51	9.81	140	13.57	15.65	800	32.45	37.42
60	8.89	10.25	150	14.22	16.20	900	34.54	39.84
65	9.25	10.66	200	16.22	18.71	1000	36.28	41.83

EXAMPLE.—Suppose a lighthouse 250 feet high. and the observer's eye on a steamer's bridge elevated to 30 feet.

30 ft. = naut. miles...... 6.28
250 ft. = naut. miles......18.14

Distance between = 24.42 nautical miles.

SHIP'S PAPERS.

All merchant vessels have on board some official document, or voucher, to prove her nationality, issued by the authorities of her country. The official voucher of a vessel which belongs to a country possessing a register of its mercantile marine, is a certificate of her registry; in other cases its form varies and is called by different names, such as "passport," "sea-brief," etc.

Certificate of Registry.—This is a document signed by the registrar of the port to which the vessel belongs, and usually specifies the ship's name and name of the port to which she belongs, tonnage, etc; name of her master; particulars of her origin, and the names and description of her registered owners.

Passport.—This is a requisition on the part of a state or sovereign power to allow a vessel to pass freely with her company, passengers and merchandise without hindrance, seizure, or molestation, as being owned by citizens or subjects of such state or soverign power. This usually contains the name of the master, the name, description and destination of the vessel.

Sea-Brief.—The sea-brief, or sea-letter, is a document issued by the civil authorities of the port from which the vessel is fitted out; it entitles the master to sail under the flag and pass of his nation; and it specifies the nature and quantity of the cargo, its ownership and destination.

Charter Party.—This is a written contract by which a vessel is let in part or in whole. The person hiring is called the charterer. It is executed by the owner or master, and by the charterer. It usually specifies (with other things) the name of the master, name and description of the vessel, the port where she was lying at the time of the charter, name and residence of the charterer, nature of the cargo to be shipped, port of loading, port of delivery and the amount of freight to be paid.

Official Log Book.—This is the log book which the master is required to keep in the form prescribed by the municipal law of the county to which the ship belongs.

Ship's Log Book.—This is usually kept by the mate, subject to endorsement by the master. It is kept for the information of the owner, and for future reference. If properly filled in. it is sometimes very useful in the settling of cases of damage caused by stress of weather, etc.

Builder's Contract.—On a vessel which has not changed hands since construction, this is usually found. It is not a necessary document, but it sometimes serves, in the absence of the pass or sea-letter or certificate of registry, to verify the nationality of a vessel.

Bill of Sale.—An instrument by which a vessel is trans-

ferred to a purchaser. It should be required whenever a sale of a vessel is alleged to have been made, either during war or just previous to the commencement of a war, and if there is any reason to suspect that the vessel is liable to detention, either as an enemy's vessel, or as an American or allied vessel trading with the enemy.

Bill of Lading.—Bills of lading usually accompany each lot of freight. The bill of lading on board ship is a duplicate of the document given by the master to the shipper of the goods or freight shipped. On it are specified the name of the shipper, date and place of shipment, name and destination of such goods, and the amount of freight to be paid on that particular lot of goods for which the bill of lading is made out.

Manifest.—This is a list of the cargo on board. It contains the mark and number of every package, the names of shippers and consignees, a specification of the quantity of goods in each package, as coffee, sugar, molasses, etc. and an account of the freight corresponding with the bills of lading. It is usually signed by the ship broker who clears the vessel out at the custom house, and by the master.

The Clearance is the custom house certificate, given at the last port from whence the vessel came. It shows that the customs duties have been paid, and it specifies the cargo and its destination.

The Crew List, or Muster Roll, contains the name, age, rating, place of residence and place of birth of every member of the ship's company.

Shipping Articles.—The agreement for the hiring of seamen. They are signed by all members of the crew, which includes the various departments, and should describe accurately the voyage, and terms under which seamen, or members, engage.

Bill of Health.—This document certifies that the vessel comes from a port where no contagious disease prevails, and that all of the crew were free from any such contagion at the time of her departure.

ROPE, CHAINS, ETC.

Practical Rule for Finding the Strength of Hawser-laid Rope.—Square the circumference and divide by 3 for the breaking strain, in tons; by 4 for the proof strain; by 6 for the working strain.

To Find What Weight a Rope Will Lift When Rove as a Tackle.—Multiply the weight the rope is capable of suspending by the number of parts at the movable block, and subtract one-fourth of this for resistance.

To Ascertain the Relative Strength of Chain and Rope.—Consider the proportional strength to be 10 to 1, using the diameter of the chain and the circumference of the rope. Half-inch chain may replace 5-inch rope.

RELATIVE SIZES OF CHAIN OR WIRE WHICH MAY BE SUBSTITUTED FOR HEMPEN ROPE.

HEMP.	CHAIN.	WIRE.	HEMP.	CHAIN.	WIRE.
Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
3	5/16	1½	8	⅞	3½
4	⅜	1¾	9	1	4
5	½	2	10	1⅛	4½
6	⅝	2½	11	1¼	5
7	¾	3			

COMPARISONS IN WIRE, CHAIN AND ROPE.

Patent Flexible Steel Wire Cables.				Chain Cable.				Tarred Hemp Rope.		
Circumference.	Weight per Fathom.	Breaking Strain.	Diameter of Sheave or Barrel.	Size.	Weight per Fathom.	Proof Strain.	Breaking Strain.	Size.	Weight per Fathom.	Breaking Strain.
Inch's	Lbs.	Tons.	Inch's	Inch's	Lbs.	Tons.	Tons.	Inch's	Lbs.	Tons.
12	115	320	72							
11	97	270	66							
10	80	220	60							
9	65	180	54							
8	53	150	48	2 5/16	280	96¼	134¾	25	146	125
7½	47	130	45	2 3/16	256	86⅛	120½	24	134	115
7	41	116	42	2 1/16	231	76½	107 1/10	23	123	106
6½	37	102	39	1 15/16	204	67½	94½	21	106	89
6	33	88	36	1 ¾	166	55⅛	77⅛	19	84	72
5½	28	74	33	1 ⅝	143	47½	66½	17	67	60
5	23½	64	30	1 7/16	112	37⅛	55½	15	56	50
4½	15	39	27	1 ⅛	68	22¾	34⅛	13	39	34
4	12	33	24	1	54	18	27	12	33	29
3½	9	26	21	15/16	48	15 8/10	23 7/10	11	28	24½
3¼	8	22	19½	13/16	35	11⅞	17 8/10	10	23	20
3	7	18	18	12/16	30	10⅛	15⅛	9	19	16½
2¾	5½	15	16½	11/16	25	8½	12¾	8½	16¼	14
2½	4½	12	15	—	—	—	—	7½	13	11½
2¼	3¾	9	13½	10/16	21	7	9½	6½	11½	10
2	2¾	7	12	—	—	—	—	5¾	9	8
1¾	2	5½	10½	9/16	17	5½	7¼	5	6¼	6
1½	1¾	4	9	—	—	—	—	4	4	4
1¼	1	2½	7½	½	14	4½	6	3½	3	2¾
1	¾	1¾	6	—	—	—	—	2¾	2	1¾

If the rope only passes over a sheave, the diameter of the sheave may be one-sixth less than if it passed completely round a barrel, but in every case, the diameter of either sheave or barrel should be as large as practicable.

PAINTING SHIP.

In all ordinary colors white lead is the principal ingredient. A good quality should be obtained, as cheap lead contains "byrates," which kills the body of it, and makes it less proof against the weather. White lead improves by keeping. The oil and turpentine used in mixing should be thoroughly incorporated with the lead. Half an ounce of patent dryers is the proportion to one pound of color.

Zinc white is said to be more durable than white lead, although it has less body. It is very pure.

Vegetable black is a cheap and good black for ordinary purposes. When dry it resembles soot, and being free from grit does not require grinding. It should always be mixed with boiled oil.

Vermilion, while in a powder, can be tested by placing a dust of it on clean white paper, and crushing it with the thumb nail. If pure, it will not change color by rubbing; but if adulterated, it will become a deep chrome yellow, or assume the appearance of red lead, showing the stuff used in its adulteration. This accounts for the unstable quality of inferior vermilion. If two coats are necessary, both must be of the best quality to insure success.

The most serviceable blue is French ultramarine. It is a permanent, kindly working color, and affords a variety of clear tints when mixed with white. It is a brilliant blue, and preserves its purity when reduced in tone by the addition of white. It may be deepened by Russian blue or indigo, or by a trifling addition of vegetable black.

Green, like black, must be mixed with boiled oil, or boiled oil and varnish; and not with linseed oil and turpentine.

The allowance of paint for well regulated vessels is based on the calculation that all weather work outside and inside has one coat every four months; and between decks one coat every twelve months. This is considered to give paint enough for boats, etc.

One pound of stiff white paint with the necessary thinnings, is supposed to cover about five and one-half square yards of smooth surface. The same quantity of black about eight square yards.

PROPORTIONS FOR MIXING.

PROPORTIONS FOR	BLACK.	WHITE	RAW LINSEED OIL.	BOILED LINSEED OIL.	TURPENTINE.	LITHARGE.
	lbs.	lbs.	Gals.	Gals.	Gals.	Gals.
Outside.......	100	....	2¼	2¼	¼	5⅓
Outside.......	....	100	3⅓	....	¼	3½
Upper deck—Weather deck	....	100	2	....	1	3½
Between dks—Cabins, Boats, etc.	....	100	1¼	....	1¼	3⅓

Litharge should always be ground in oil, and on no account must it be put in paint in a dry state. It should not be mixed in paint until it is about to be used.

MIXING COLORS.

Cream Color.—Crome yellow, the best Venetian red and white lead.

Fawn Color.—Burnt sienna, ground very fine, mixed with white lead.

Drab.—Raw or burnt umber and white lead, with a little Venetian red.

Purple.—White lead, Prussian blue and vermilion.

Violet.—White lead, French ultramarine, vermilion, and a very little black.

French Gray.—White lead and Prussian blue, tinged with vermilion.

Salmon Color.—White lead, tinged with the best Venetian red.

Imitation of Gold.—Mix white lead, chrome yellow and burnt sienna until the proper shade is obtained.

USEFUL RECIPES.

A good coating for Tarpaulins.—Add twelve ounces of beeswax to one gallon of linseed oil; boil two hours; prime the cloth with this mixture, and use it instead of boiled oil for mixing the coating.

Copper Color Paint.—Six parts of spruce ochre, one part of Venetian red and one part of black.

Bronze Paint.—Chrome green, two pounds; ivory black, one ounce; chrome yellow, one ounce; good Japan, one gill. Grind all together and mix with linseed oil.

Removing Old Paint.—Nothing is so efficacious as heat, applied by a small brazier with a handle.

One part of pearl ash mixed with three parts of quick stone lime (slacking the lime in water and then adding pearl ash), laid over paint work, and allowed to stand fourteen to sixteen hours, will so soften it, that it can be easily scraped off.

Putty.—Well dried and sifted whiting, 100 pounds, and

one and three-fourths gallons of linseed oil well mixed, left for three days, and then worked up again before using.

Spar Varnish.—Boiled oil and resin.

Marine Glue.—One part india-rubber, twelve parts mineral naphtha; heat gently, mix and add twenty parts of powdered shellac. Pour out on a slab to cool; when used to be heated to about 250° Fahr.

Glue to Resist Moisture.—Glue which has been swelled by water dissolved in linseed oil.

Glue Cement to Resist Moisture.—One pound glue, one pound black resin, quarter pound red ochre, mixed with the least possible quantity of water.

Cement for Cloth or Leather.—Sixteen pounds of gutta-percha cut small, four pounds india-rubber, two pounds pitch, one pound shellac, two pounds linseed oil, melted together and well mixed.

Waterproofing for Boots.—One quart linseed oil, six ounces of beeswax, four ounces spirits of turpentine, one ounce Burgundy pitch. Melt wax and oil together and dissolve the pitch in the turpentine, pour both into a jar, and place it in a saucepan with water, boil and stir till well mixed. Being very inflammable, beware of fire getting near it.

Yellow for Smokestacks.—Whiting 37 pounds, yellow ochre 74 pounds, glue 6 pounds. The glue is made into size and added hot to the whiting, etc., mixed with water enough to give the proper consistency for use.

White.—Whiting 37 pounds, glue 6 pounds.

French Polish.—Five ounces of naphtha, one ounce of shellac, one dram of myrrh, ten grains of isinglass and six drams of olive oil.

INTERNATIONAL CODE FLAGS AND PENNANTS.

A = White and Blue Swallow-tail.
B = Red Swallow-tail.
C = White pennant with red ball.
D = Blue pennant with white ball.
E = Red white and blue pennant.
F = Red pennant with white cross.
G = Yellow and blue pennant.
H = White and red square.
I = Yellow square with black ball.
J = Blue white and blue, horizontal, square flag.
K = Yellow and blue square.
L = Yellow and black in 4 squares.
M = Blue square with white diagonal cross.
N = Blue and white in 16 squares.
O = Yellow and red, separated diagonally, square flag.
P = Blue square with white square in center.
Q = Yellow square.
R = Red square with yellow cross.
S = White square with blue square in center.
T = Red white and blue, vertically, square flag.
U = Red and white in 4 squares.
V = White square with red diagonal cross.
W = Blue white and red square, border blue, center red.
X = White square with blue cross.
Y = Yellow and red diagonal stripes, square flag.
Z = Black, yellow, blue and red, in 4 triangles, forming a square.

The "Code Flag" and or "Answering Pennant" is a pennant with red and white vertical stripes.

When used as the "Code Flag" it is to be hoisted under the Ensign.

When used as the "Answering Pennant" it is to be hoisted at the mast head or where best seen.

GENERAL RULES FOR SIGNALING BY THE INTERNATIONAL CODE FLAGS.

Ship A wishing to signal, hoists her Ensign with the Code Flag under it.

Ship B answers by hoisting her Answering Pennant at the "Dip," that is about two thirds up.

Ship A now makes the signal desired, first hauling down her Code Flag if required to make the signal.

When A's signal is understood by B and found in the Signal Book, B hoists her Answering Pennant "Close Up," and keeps it there until A hauls down.

B then lowers her Answering Pennant to the "Dip" and waits for the next signal from A; and so on.

Each hoist that A makes should be kept flying until B answers with her Answering Pennant "Close Up."

When A has finished signaling, she hauls down her Ensign, and the Code Flag if not already down.

The Answering Pennant should be hoisted where best seen.

Signal Flags should always be hoisted where they can best be seen; not necessarily at the mast head.

To make a signal, look for the principle word in the communication you wish to make (pages 143-451), in the Signal Book, and there find the Code Flag letters of the flags to be hoisted.

To interpret or decipher a signal made, find the flag letters in alphabetical order in the Signal Book, and beside these will be found the meaning of the signal.

Urgent and important signals are *Two flag signals.*

General signals are *Three flag signals.*

Geographical, alphabetical spelling tables, and vessel's numbers are *Four flag signals.*

The Signal Book has Three Parts, namely:

1st part, Urgent and Important;

2nd part, General Index, arranged alphabetically;

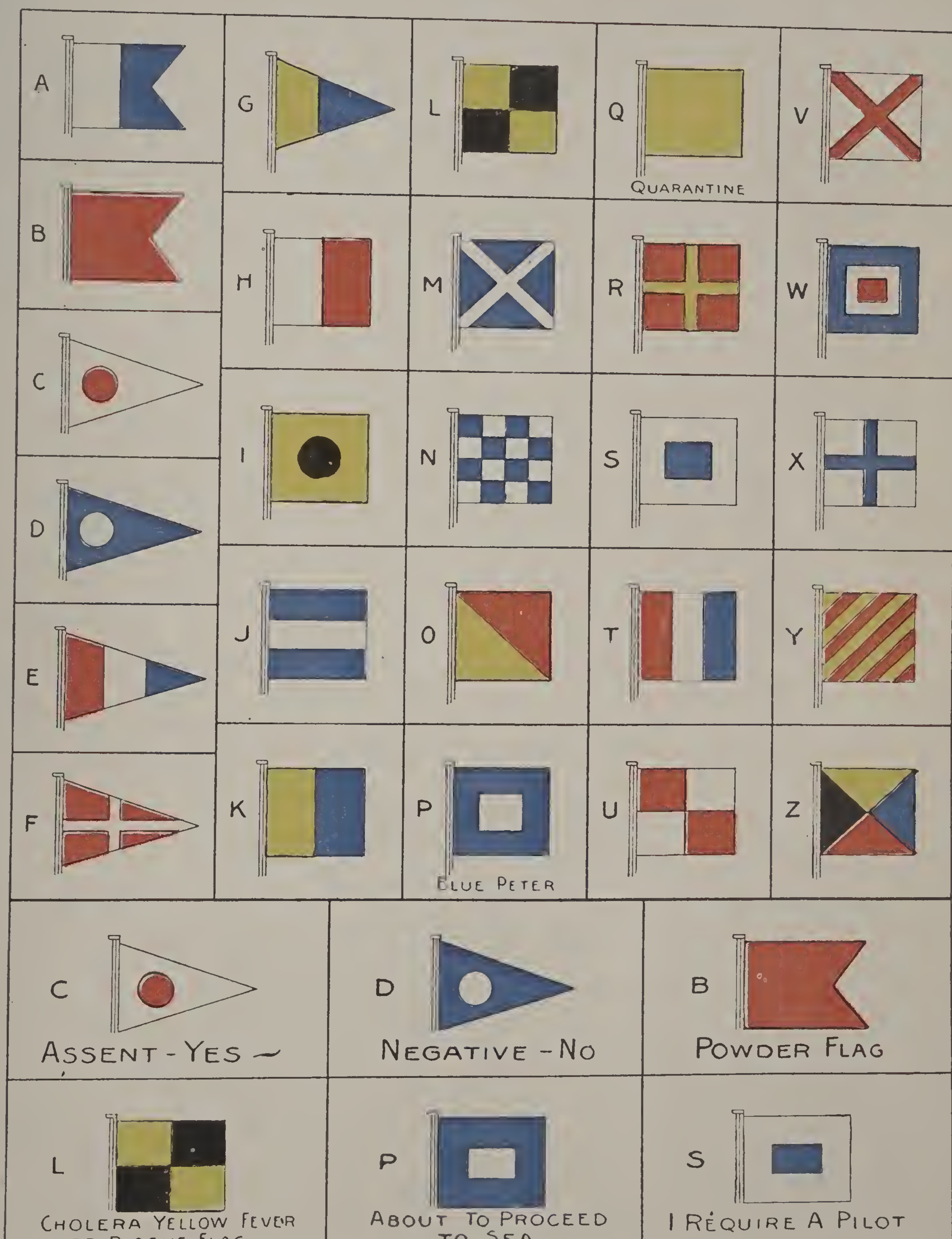
3rd part, Lists of U. S. Storm-warning, Life-saving and Wireless Stations, Etc.

NEW INTERNATIONAL CODE FLAGS.

CODE FLAG" AND "ANSWERING PENDANT."

When used as the "Code Flag" it is to be hoisted under the ensign.

When used as the "Answering Pendant" it is to be hoisted at the mast-head or where best seen.



NOTE—From January 1, 1902, the use of the New International Code Flags is compulsory and they only will be recognized.

DESCRIPTION AND USE OF THE FOGOMETER, WITH ACCOMPANYING DIAGRAM, AND DISTANCE TABLES FOR READY REFERENCE

Patented July 12, 1910 by W. J. Smith, Master Mariner, President The Seattle Nautical School, 507 Maritime Building, Seattle, Wash.

This is an instrument for facilitating the process of accurately determining a ship's position (both as to the bearing of, and the distance from a light-house, etc.) in foggy weather, by the use of wireless telegraph and sound waves, when within hearing distance of a wireless shore station, the ship having a wireless outfit.

It is well known that sound in air travels 1123 feet per second, at a temperature of 60 deg. Fahr. This may be used for all practical purposes. Wireless waves however travel with the speed of light, i. e. 186,330 **miles** per second. The velocity of sound in sea water is 4593 feet per second.

If a wireless station sends a "wireless' simultaneously with the regular sound signal used during fog, the time interval in seconds between tick of wireless instrument on board and the moment when the sound signal reaches the ear, multiplied by 1123, and the result divided by 6080 (feet in a naut. mile), will equal the distance off, and the ship will be somewhere on the arc of a circle at that distance from the shore station. Now, if the ship be run on her course for a certain distance by log, and her distance off again found by wireless and sound as above, she will again be somewhere on the arc of a circle at **that** (the second found) distance off. It will now be seen that we have the three sides of a triangle, and if we take the course with the parallel rule and the distance run in the interval with the dividers, and slide the former towards the shore station on the chart until the two legs of the dividers will just fall on the two arcs already described, the ship's position at time of both first and second observations will be designated by these two points thus found. These results can be readily verified by a simple caluculation of trigonometry.

All this seems like making a drawing board of the chart, but the Fogometer obviates the necessity of marking and

erasing pencil lines; and provides means whereby the foregoing results are obtainable in a most convenient and rapid manner, and with a nice degree of accuracy.

Should the vessel be within the range of a submarine fog signal station, also equipped with wireless apparatus, the time interval in seconds between tick of wireless and submarine sound received on board, multiplied by 4593, and the result divided by 6080, will give the distance off; and her position can be found by the method already described.

The accompanying tables, which are selfexplanatory, will at once give the **distance off** by inspection, when the **time interval** in seconds has been noted.

To Use the Fogometer.

Lay the instrument flat upon the chart with its side A off-shore and the arms B and C directed inshore towards the light-house, and crossed. Set the sliding block on side A to the run the ship has made between the observations and clamp it, and adjust the arms B and C to their respective distances off; then make all rigid by means of the thumb screws. The intersection of B and C is now positioned over the light-house L H as a pivotal point, and the instrument slued so as to make the offshore side A conform to the edge of the parallel rule corresponding to the ship's course. A pencil point should now be inserted in the apertures for the purpose, to mark the chart. The correct bearing of, and distance from the light-house are now assured, **using the chart scale for the distance instead of the scale of the instrument.**

It would be needless to attempt to graduate the instrument to suit the various scales on which charts are projected; and the average man will readily see that this, even if it were practicable, is unnecessary. The bearing of the shore object will be the same, no matter what scale is used. The scale, one half inch to the nautical mile has been adopted as sufficiently large to insure accurate projection on any coast chart. We assume that the graduations are nautical miles, subdivided into tenths, and use the instrument as directed. The ship will be on a line passing through the spot which marks the end of


STRAIT OF JUA
CAPE FLATTERY
MAGNETIC COMPASS
TRUE COMPASS
A
B
C
Cape Flattery Hill
Watch Point
Fuca Pillar
Duntze Rock
Duncan Rock
USC&GS
6265

TABLE I.

Distance of ship from Wireless Station, when time interval in seconds between receipt of wireless and air sound signals, dispatched simultaneously, has been noted on board.

Secs. interval.	Dist. off Wireless Station.	Secs. interval.	Dist. off Wireless Station.	Secs. interval	Dist. off Wireless Station.	Secs. interval.	Dist. off Wireless Station.	Secs. interval.	Dist. off Wireless Station.	Secs. interval	Dist. off Wireless Station.
s	Naut. miles.	s	Naut. miles.	s	Naut. miles.	s	Naut. miles.	s	Naut. miles.	s	Naut. miles.
1	.18	11	2.03	21	3.88	31	5.73	41	7.57	51	9.42
2	.37	12	2.22	22	4.06	32	5.91	42	7.76	52	9.60
3	.55	13	2.40	23	4.25	33	6.10	43	7.94	53	9.79
4	.74	14	2.59	24	4.43	34	6.28	44	8.13	54	9.97
5	.92	15	2.77	25	4.62	35	6.46	45	8.31	55	10.16
6	1.11	16	2.96	26	4.80	36	6.65	46	8.50	56	10.34
7	1.29	17	3.14	27	4.99	37	6.83	47	8.68	57	10.53
8	1.48	18	3.32	28	5.17	38	7.02	48	8.87	58	10.71
9	1.66	19	3.51	29	5.36	39	7.20	49	9.05	59	10.90
10	1.85	20	3.69	30	5.54	40	7.39	50	9.24	60	11.08

DEFINITION.

Sound travels 1123 feet per second in air at a temperature of 60° Fahr. This may be used for all practical purposes. Wireless travels with the speed of light, 186,330 miles per second. Distance off=secs. interval between tick of instrument and sound of shore signal $\times 1123 \div 6080$.

TABLE II.

Distance of ship from Wireless Station, when time interval in seconds between receipt of wireless and submarine sound signals, dispatched simultaneously, has been noted on board.

Secs. interval.	Dist. off in Naut. miles.	Secs. interval.	Dist. off in Naut. miles.	Secs. interval.	Dist. off in Naut. miles.	Secs. interval.	Dist. off in Naut. miles.
1	.76	6	4.53	11	8.31	16	12.09
2	1.51	7	5.29	12	9.07	17	12.84
3	2.27	8	6.04	13	9.82	18	13.60
4	3.02	9	6.77	14	10.58	19	14.35
5	3.78	10	7.55	15	11.33	20	15.11

DEFINITION.

Sound in sea water travels 4593 feet per second. Distance off =seconds interval between tick of instrument and sound of submarine signal $\times 4593 \div 6080$.

TABLE III.

Distance of ship from that part of the land (etc.) from whence an echo is returned, when the time interval in seconds between sound of whistle (ship's gun, etc.) and return of echo has been noted.

Secs. interval.	Dist. off in Naut. miles.	Secs. interval.	Dist. off in Naut. miles.	Secs. interval.	Dist. off in Naut. miles.	Secs. interval.	Dist. off in Naut. miles.
1	.09	16	1.48	31	2.86	46	4.25
2	.18	17	1.57	32	2.96	47	4.34
3	.28	18	1.66	33	3.05	48	4.43
4	.37	19	1.75	34	3.14	49	4.53
5	.46	20	1.85	35	3.23	50	4.62
6	.56	21	1.94	36	3.32	51	4.71
7	.65	22	2.03	37	3.42	52	4.80
8	.74	23	2.12	38	3.51	53	4.89
9	.83	24	2.22	39	3.60	54	4.99
10	.92	25	2.31	40	3.69	55	5.08
11	1.02	26	2.40	41	3.79	56	5.17
12	1.11	27	2.49	42	3.88	57	5.26
13	1.20	28	2.59	43	3.97	58	5.36
14	1.29	29	2.68	44	4.06	59	5.45
15	1.39	30	2.77	45	4.16	60	5.54

DEFINITION.

As sound travels 1123 feet per second, and 6080 feet equal one nautical mile: Then dist. off $=(\text{secs. interval between sound and echo} \times 1123 \div 2) \div 6080$.

the run, and the light-house, and her distance off on that line will be found by using the chart scale, and distance determined at second observation. If the chart scale is larger than that of the instrument she will be outside the marked spot on a projection of the line, but inside if the chart scale is smaller.

For Example:

A steamer is approaching the Strait of Juan de Fuca from the southward in a dense fog. He is within hearing distance of Tatoosh (Cape Flattery) wireless station but uncertain of it correct bearing and distance away. He calls the light house by wireless and requests the operator to dispatch wireless and sound waves simultaneously, and to repeat the dual signal in say thirty minutes. The wireless instrument is now closely watched and the sound signal listened for, and the time interval between the signals received as noted is say 41½ seconds. Reference to Table I. shows the distance off to be 7.7 miles (naut.). Thirty minutes later, the interval between wireless and sound as noted on board is say 27½ seconds, for which interval the same table gives 5.1 miles. During the interval between the observations, the ship steaming 11 knots per hour has covered 5½ miles of distance on a course N. 10 deg. W. magnetic. The accompanying diagram will show the case in hand. Now set the sliding block on side A of the instrument to the ship's run 5½ miles and clamp it, and adjust the arms B and C to correspond to the distances off obtained, i. e. 7.7 and 5.1 respectively, and make all rigid by the thumb screws. The instrument is laid upon the chart with side A offshore and the intersection of B and C positioned over the light house. Slue the instrument till side A conforms to the edge of the parallel rule containing the course, and mark the chart with a pencil point through the aperture at the end of the run. The ship is now on the line passing through this mark and the light-house, and her actual distance off can be measured by the chart scale, while the parallel rule and the compass rose on the chart will give the correct bearing of the light-house. Arms B and C and be used interchangably to suit the ship's course along the coast either way.

Shore stations may be called upon to despatch sound and wireless waves simultaneously at intervals as desired; and it is highly probable that in the near future it will become an established custom for these stations to send such simultaneous dispatches at stated intervals during fog, as an additional aid to navigation.

RULE FOR LONGITUDE BY SUNRISE OR SUNSET.

Get the Mean Time at Greenwich and correct the Declination and Equation of Time, and find the Polar Distance, as usual.

To the Dip for height of the eye add the Refraction for 0 deg. Altitude; then add the Semidia. and subtract the Parallax in the case of an Upper Limb, but subtract both Semidia. and Parallax for a Lower Limb observation. The result in either case is the Negative Altitude.

Add together the Latitude and Polar Distance, and from the sum subtract the Negative Altitude; divide what remains by 2 for the Half Sum, and to the Half Sum add the Negative Altitude, and thus obtain the Remainder. Now proceed in the usual way for the Hour Angle, and thence the Longitude.

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